ON

THE STRUCTURE AND USE

OF

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BY

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TO

THE PHYSICIANS AND SURGEONS

OF

ST. GEORGE'S HOSPITAL,

THIS WORK IS DEDICATED,

BY THEIR FRIEND AND PUPIL,

THE AUTHOR.

PREFACE.

THIS work was written in competition for the munificent prize endowed by the late Sir Astley Cooper, and the Adjudicators—the Physicians and Surgeons of Guy's Hospital—honoured the author by their decision in its favour.

The author, during the progress of his work, received considerable assistance from many to whom he now begs to acknowledge his deep obligations.

In the historical portion of his essay, he received much valuable assistance from his friend, Mr. T. Holmes, in the compilation of the statements and opinions of the ancient writers.

For the large number of analyses of the blood of the spleen, and of the spleen itself, the author is indebted to his kind friend and most able colleague, Dr. H. M. Noad.

The ultimate analyses of the spleen, as well as some of those on the blood itself, were made by my friend, Mr. Henry Pollock, in the Laboratory of the St. George's Hospital Medical School, under the superintendence of Dr. Noad.

The dissections recorded in the fourth chapter on the Comparative Anatomy of the Organ, the author owes to the liberality of the Council of the College of Surgeons, who permitted him to have the freest access to their valuable collection of store preparations.

The author, in conclusion, begs to acknowledge his deep obligations to his esteemed friend, Mr. Athol Johnson, who has with much trouble revised the work in its passage through the press.

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PART I.

HISTORICAL INTRODUCTION.

IN the imperfect records left of the anatomy of the ancient Egyptians, no trace of any knowledge of the spleen can be ascertained.

In the Treatise 'De Carnibus,' ascribed to Hippocrates, the following peculiar account of the organ is given:—'The spleen is composed thus: with the hot and the viscid (principles) a great deal of the hot and very little of the cold, only so much as is sufficient to fix the viscid part of it; that is, the fibres which are in the spleen: and it is through these fibres that the spleen is soft and fibrous.'[2] He states that its use was to draw the watery part of the food from the stomach, as the gall-bladder draws the bile from the liver. Its shape resembles the print of the foot, and

[1] The etymology of the word is doubtful; the ancients state that the word σπλην is derived from σπλαγχνον (a viscus), others derive it from the Greek word σπαω (traho), to draw, because they supposed that it drew to itself the spoiled parts of the blood.

[2] HIPPOCRATES. *De Carnibus.* B.C. 431.

that next to the head is the most hollow part, and is full of cavities and has most spaces, having also wide and thick veins of a spiral form. (Hippocrates *De Anat. et de Morbis.*) He notices also the diseases of the organ and their treatment in his works *De Internis Affectionibus*, and *De aere, aquis, et locis.*

The celebrated Greek philosopher Aristotle, at a somewhat later period,[1] described its position and attachments in the human subject; he noticed also its connexion with the great vein, (vena portæ.) In his dissections of animals he observed that those which are oviparous have the organ so small as to have escaped the notice of some, as in most birds and some of the reptilia—a fact confirmed by many since his time. He believed that its use was to draw away the superabundant moisture from the stomach, and to assist that organ in digestion.

Diocles of Caristus, who flourished a little time after Aristotle, confirmed the statements which his predecessor had advanced.

A period of repose ensued for several centuries, until two celebrated anatomists arose in the Alexandrian school, who, favoured by the permission of Ptolemy Lagus, the first of the Egyptian princes, with diligent research elaborately dissected the human body. These were the celebrated Herophilus, and Erasistratus, the pupil of Chrysippus, his contemporary; their researches were such as completely to overthrow the mystic opinions of many of their

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[1] Aristoteles, *De Animalium Historiâ.* Lib. x. pp. 23, 44, 46, 57.

predecessors, and were the means of giving to anatomy the rank of a true science. They did not, however, advance much the anatomy of the spleen, for the latter author states that it has no function; but his followers, condemning the negligence of their teacher (as Galen states), said that nature gave animals a spleen to prepare the chyle expressed from the food, for the liver, for the generation of blood.

Celsus merely refers to its position, and its soft and thin nature, not giving any account of its structure or probable function.[1]

Rufus Ephesius[2] does little more than allude to its position. Its colour he likens to wine lees; its consistence loose and spongy, and composed of a network of vessels, inactive, and without vital energy; he states that it has no use.

In the works of Aretæus[3] and Paulus Ægineta[4] no fresh addition appears to have been made to our knowledge of the anatomy of the spleen, the latter author believes that its use is to attract from the liver the melancholic humour which is, as it were, the lees of the blood, the superfluous quantity being expelled

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[1] AURELIUS CORNELIUS CELSUS, *De re Medicâ.* Venetiis, 1566. Lib. quartus—'De humani corporis interioribus sedibus.' 'At lien è sinistra non eidem septo, sed intestino innexus est, naturâ mollis et rarus, longitudinis crassitudinisque modicæ; isque paulum a costarum regione, in uterum excedens maximâ parte sub his conditur. Atque, hæc quidem juncta sunt.'

[2] RUFUS EPHESIUS. Parisiis, MDLIIII. Περι Ανθρ. Μορ. P. 44.

[3] ARETÆI, CAPPADOCIS, *Opera Omnia.* Lipsiæ, 1828.

[4] PAULUS ÆGINETA. Translated from the Greek by Francis Adams. Sydenham Society, Vol. i. p. 577.

to the orifice of the stomach to excite the appetite. This physiological conclusion he then applies in explanation of the pathological changes produced in the system by disease of the gland.

Julius Pollux,[1] at a somewhat later period, merely notices the existence of the gland, and mentions that its position is on the left side.

The views of the function of the spleen about this time advanced by one of the most celebrated of all the ancient physiologists, Galen,[2] are interesting, as they are founded upon the results of anatomical examination, and the almost universal assent with which these opinions were received for many years, showed the respect with which all the statements of this great philosopher were entertained. He believed that the spleen attracted, by its great vein, the thick and muddy juices generated in the liver, and, after undergoing some changes in the substance of the gland, materially assisted and perfected by the arteries, part of this juice was transformed into aliment for the spleen, whilst that part not capable of transformation was transmitted by a series of veins into the cavity of the stomach in the form of an excretion.

This opinion as to its function received universal assent, not only from the physiologists of his time, and the Arabians, Avicenna, &c., but prevailed through the

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[1] JUL. POLLUCIS, Ονομαστικον. Vol. i. p. 259.

[2] GALENI *Opera, De usu partium corporis.* Venetiis, 1550. Vol. i. p. 140, cap. 15, 16; lib. iv.

ages of darkness and barbarism, and was even defended by those anatomists who lived in the commencement of the 16th century, at a time when science and literature were again revived, and when the intellectual powers became again roused, after a repose of more than a thousand years. Thus Guinterius[1] follows Galen's description of its structure almost in the same words, and believes its function similar to that ascribed to it by that celebrated writer.

Estienne[2] not only adopts the same opinion of the spleen excreting the melancholic juice, but states that there is a common duct from that organ to the stomach, by which the black bile regurgitates to its orifice, the use of this fluid being, as he remarks, to incite the appetite, and by its bitterness and acidity desire is produced. He also supposes that, in conjunction with the liver, it warms the stomach, and aids in the digestion of the food. There can be hardly any doubt, from the account given by this author, that he supposed the vasa brevia distended with blood to be ducts proceeding from the spleen to the stomach—an opinion soon afterwards set aside by the accurate observation of Vesalius. Although the outward form, position and attachments of the organ, as well as the course of its vessels, are mentioned

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[1] JOH. GUINTHERI *Anat. Institut.* Parisiis, 1536. Pp. 27—29. 'Corpus hujus visceris, quod parenchyma vocant, rarum et laxum est spongiæ modo, ut facilius crassos humores ex jecore alliciat.' —p. 27.

[2] CHARLES ESTIENNE, *La dissection des parties du corps humain.* Paris, 1546. Pp. 189, 197, 383.

with tolerable accuracy by Valverde,[1] Colombo,[2] Brunnfelsius,[3] and Bauhin,[4] in the same century, their description of the minute structure of the gland is imperfect, and their opinions of its use either precisely similar, or only a slight modification of Galen's.

In the same century, however, there lived some anatomists who did not bow down to the authority that Galen's learning and philosophy had inspired in nearly all, and there are none, perhaps, who assisted more to overthrow the doctrines advocated by him than Vesalius,[5] one of the greatest anatomists of that age. This author, although he did not suggest any new theory of its use, except his supposition that it assisted digestion by means of its own innate heat, concluded, from his more careful and accurate examination of the vessels of the gland, that no channel exists like the bile duct, to convey the recrementitious matter into the stomach, and that

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[1] VALVERDUS, JOHANNES. Venetiis, 1607. Pp. 187, 188, (*Anatome corporis humani*). 'Lienis functio est, sanguinem a melancholico succo emundare.'

[2] COLUMBUS, REALDUS, *De re Anatomicâ.* Venet. 1559. Pp. 230, 231. 'Lienis utilitas est, ut melancholicus sanguis ab illo attraheretur, cum præsertim eodem alendus esset. In quâ nutritione (est autem hoc observatu pulcherrimum) acidus quidam humor sejungitur et per venæ portæ ramum ad ventriculum delatus famem dormientem excitat, quæ utilitas nullo pacto spernenda est.'

[3] BRUNNFELSIUS, O. T., *Catalogus. Ju. Medicor.* 1530. P. 14.

[4] BAUHINI, CASPARI, *Anatomica corporis virilis et muliebris historia.* Lugduni, 1597. Pp. 56—58.

[5] A. VESALIUS, *Opera Omnia Anatomica.* Lugdun. Batav., 1725. Pp. 437 to 440.

the veins going there, do not arise from the substance of the spleen, but from the veins just before they enter into it; he observed, also, that their contents did not differ from that of other veins. It was by means of these simple anatomical observations that he overthrew an opinion advocated by one of the most celebrated physiologists, an opinion which, as we have seen, was supported by many able anatomists and taught in the ancient schools for more than a thousand years.

About this period a new theory of its use was suggested by Franciscus Ulmus,[1] in his Monograph, the first then published on the anatomy of this gland; a theory, however, not founded on extended observations on the anatomy of the organ. He supposed that its office was to prepare blood for the heart and arteries; the material from which it is formed being the chyle, which is brought from the stomach by a large vein (the gastric) to the spleen, and by a branch of the vena portæ, the formed blood being returned to the heart by the splenic artery and aorta. Fel. Plater[2] also believed that its office was rather in the elaboration of blood, than in the attraction of the melancholic juice, although he explained the method by which it was elaborated differently to Ulmus. This author also argued that as all azygous parts are placed in the median line of the body, the spleen cannot be one, as it

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[1] Francisci Ulmi, Pictaviensis, Doctoris Medici, *De Liene libellus in Miscel. Med.* Vol. iii. 1578.

[2] Fel. Plater, *De corporis humani structurâ et usu.* Basil, 1583. P. 185.

corresponds in situation and structure with the liver, and therefore must be the liver of its own side, an opinion which he attempted to prove by many arguments. Plato, in Timæus, makes mention of the same fact.

Hoffman,[1] in his Essay, considers chiefly the opinions of the ancients, and more particularly those of Aristotle and Galen, regarding the structure and use of this gland, adding no original observations. He then defends Aristotle's opinion, and makes his own suit both Galen's and Aristotle's. His own appears to be that it draws to itself the thinner and more watery parts of the blood, and of the chyle, just as it is undergoing transformation into blood, and separates from it (the chyle) the earthy particles forming the black bile, as an excrement, and also secretes blood of a thinner character than that of the liver. Veslingius[2] and Marchettis[3] also about the same period adopt a similar view. Spigal[4] adheres to the opinion of Aristotle, that it, with the liver, assists the digestion of the food; he also adopts the views of Hoffman, and oddly observes that, as it purges the blood of its thick

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[1] Casp. Hoffmannus, *De usu lienis, cerebri, et de ichoribus.* A.D. 1639. Lugd. Bat.

[2] Johannes Veslingius, *Syntagma Anat.* Padua, 1647. Pp. 43, 44. 'Actionem lienis, ex majore doctorum consensu, constituo confectionem sanguinis, ex aquosiore chyli portione admistisque partibus terreis sordidâ.'

[3] D. de Marchettis. Patavini, 1656. Pp. 46 to 49. 'Lienem esse humoris melancholici, hoc est sanguinis melancholici, receptaculum, ad sui nutritionem, et hoc asseremus, quo usque probabiliorem opinionem inveniemus.'—p. 47.

[4] A. Spigal. Amsterdami, A.D. 1645.

humours, it is therefore larger in man than in other animals, as he, being the wisest of animals, requires the purest blood. 'Ut defæcari sanguis felicius queat à crassis humoribus, cum homo animal sit sapientiæ studio addictum, at sanguis quo tenuior est et purior, eo sapientiores reddere dicitur.'—Arist. lib. ii. de part. *Animant.* cap. 11, p. 242.

In the description given by Riolanus[1], he brings forward many observations, original in themselves, which show the incorrectness of Galen's opinion, viz., that the spleen is nourished by the melancholic juice; he shows, for instance, that the blood found in the spleen is no different to that found in the liver; that the splenic vein does not arise from the liver; and that no evacuations of black humour are ever found in the stomach or intestines of healthy subjects; a fact that might easily be observed, if such were conveyed by the spleen to that organ. Yet notwithstanding these observations, so impressed was he with the authority which the ancients inspired in nearly all, that he brings forward an opinion on the use of the gland that reconciles those of Hippocrates and Aristotle with that of Galen. The anatomical knowledge that was hitherto possessed appears merely to relate to the outward form and connexion of the several organs—a task which the first great Italian anatomists achieved; but no very considerable progress had as yet been made in the minute structure of the several organs, to determine which was the only

[1] Johannes Riolanus, *Opera Anat.* Paris, 1649. Pp. 129 to 140.

sure road for the advancement of any knowledge regarding their use. The celebrated discovery, however, of the circulation by Harvey[1] about this period, and Aselli's[2] careful observations on the course of the lacteal vessels, served not only to dispel many of the preceding erroneous doctrines, but also assisted, more than perhaps any other discoveries, in the furtherance and enlightening of physiology.

Although some traces of these more minute investigations may be found in some of the preceding writers,[3] little progress was made in this department of anatomy until about the middle of the seventeenth century. About this period, Highmor[4] gives a far more minute description of the spleen than any preceding writer. He describes its external tunic, and the trabeculæ, as arising from its inner surface; these latter being solid fibres which form complicated nets around which the parenchyma adheres. The vessels he also describes very minutely, both in man and animals, and points out the differences between them, mentioning the existence of valves in the veins of the latter, which prevent the reflux of blood into the spleen. Notwithstanding these more extended observations on the structure of the gland, his opinion

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[1] HARVEII *Exercit. Anatomica de motu cordis, et sanguinis circulatione in animalibus.* Francof. 1628.

[2] CASP. ASELLIUS, *De lactibus, seu lacteis, seu lacteis venis, quarto vasorum mesaraicorum genere.* Mediolan., 1627.

[3] VESALIUS, RIOLANUS, BAUDIN.

[4] NATHANIEL HIGHMOR, *Corporis humani disquisitio anatomica.* Hagæ, 1651. Pp. 59—74.

of its function is singularly unhappy, as by his own statement it refutes itself. He believed that the melancholic juice was brought to the spleen by the arteries from the cœliac, after it has undergone its last concoction in the heart; that the spleen ferments and separates it, applying a portion of the separated blood to its own nutrition; what is left of the purer blood flows by the splenic vein through the liver into the cava, and then to the heart, that it may acquire heat and spirits from the heart, and be driven free from all excrement by the aorta for the nutrition of all parts.

In Glisson's[1] elaborate Monograph, which followed soon after, many peculiar and original opinions are found on the structure and use of the spleen. His description of the vessels of the organ is similar to Highmor's, but he believes that the trabeculæ are nervous fibres, and that the nerves which accompany the vessels, are continuous with these. Glisson appears to be the first author who describes the nerves as supplying the interior of the spleen; he assigns to them the office of strengthening the soft and spongy parenchyma, and believes that their real use is as auxiliaries to the nerves, serving to secrete from the arteries an aqueous humour, which is carried away either immediately by the nerves, or through the mediation of the brain and spinal cord is distributed into the nerves of the whole body, as well as also into the nerves of the adjacent parts, such as the supra-

[1] Glisson, Francis, *Anatomia hepatis.* Londini, 1654. P. 429.

renal capsules: 'Ideoque oportet aliquid è liene educant, quod deinde in superiorem abdominis plexum transferant, unde postea, datâ occasione, vel immediatè per nervos sexto pari connexos, vel mediantibus cerebro et medullâ spinali, in omnes totius corporis nervos distribuatur.' P. 432. He denies the existence of an excretory duct, or of lymphatic vessels: 'Lymphæ ductus nullos vidimus eosque propterea si qui adfuerint aliorum oculis perspicacioribus detegendos relinquimus.'

Wharton,[1] in his learned dissertation on the glands, which made its appearance soon after Glisson's, adopts his theory of its office being secretory, and of its ministering to the nerves, serving, he says, to extract, by its parenchyma and nervous fibres, an aqueous liquor from the blood, thus, he observes, showing that it has some analogy with the glands, all of which are supposed by him to have a similar function. But in the same chapter in which he considers 'an lien sit glandula,' he concludes that it should not be classed with them, on account of the differences observed by him in the structure of the parenchyma, and in the organization and distribution of the vessels and nerves.

Schenck,[2] in a highly elaborate paper on the spleen, in his *Exercitationes Anatomicæ*, adopts the opinions of Wharton, and considers that it is not a glandular

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[1] WHARTONO, THOMÂ, *Adenographia sive glandularum totius corporis descriptio.* Londini, 1656. Pp. 14—18.

[2] SCHENCK, ICH. THEOD., *Exercit. Anat.* Jenæ, 1662. Pp. 412—453.

organ, for the same reasons as that author. In his description of its structure he confirms the accurate dissections of Highmor and others; but neither he nor Wharton mention the existence of lymphatic vessels. Its function he believes to be that of purifying the blood of its thick, melancholic, and watery portions, an office which he believed most of the glandular organs assisted in performing. Bartholinus[1] also adopted a similar opinion, believing that the blood so prepared was for the use of the viscera of the lower part of the abdomen: 'Ordinarie autem putat lienem esse organum conficiendi sanguinis, ad nutrienda viscera infimi ventris, ut ventriculum, intestina, omentum, mesenterium, pancreas, &c.,— p. 164. 'Sanguinem omnem etiam decantant, filtrant, despumant, incrassant, et à sordibus minusque utilibus particulis segregant separantque.'

This great advance in structural anatomy, and more particularly of the glands, was also much assisted by the investigations of Steno,[2] Bellini,[3] and De Graaf.[4]

About the middle of the seventeenth century, when the great revolution in science had taken place, and when Bacon had laid down the general principles and the special rules of scientific investigation, the

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[1] Thos. Bartholinus, *Anat. quartum renovata.* Lugd. Bat., 1674. P. 155.

[2] Nie. Stenon, *De glandulis oris.* Lugd. Bat., 1661.

[3] Laurent Bellini, *De structurâ et usu renum.* Flor., 1662.

[4] Regn. de Graaf, *Hist. anatom. partium generat. inservientium.* Leidæ, 1688.

elaborate researches of the great Italian anatomist, Malpighi,[1] served to give much clearer ideas of the minute structure and function of the glandular organs, and more particularly of the spleen; for to this great physiologist is due the discovery of one of the essential parts of this organ—the Malpighian bodies. It is also a curious fact that Malpighi should have assigned to them the function of secreting glands,[2] the truth of which, as well as of many other of his statements, may be shown by the almost universal assent which they have received for nearly two hundred years, and which have been more clearly proved in modern time by the indefatigable industry and careful observation of the German physiologists. He denied the nervous structure of the trabeculæ, and at first described them as consisting of a fibrous tissue which is so arranged as to support the venous cells; but he afterwards changed this opinion, and asserted their muscular contractile nature, comparing them to similar structures in the lungs, testicles, &c.,[3] the office of which he supposed was to

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[1] MALPIGHI, *De visc. structurâ exercitatio anatomica.* Bonon., 1665. Also, *Opera Posthuma.* 1696. Also, *De glandulis conglobatis.* Lond. 1689.

[2] See MALPIGHI's letter of date 1671, in *Phil. Transac.*, vol. vi. p. 2150. A.D. 1671.

[3] 'Hujus occasione communicandum tibi duxi, Lienis fibras quæ tot ingenia torsere, nequaquam nerveas (quod et aliquando ipse autumavi) sed carneas esse, ita ut ex carneo exteriori involucro, et productis transversaliter fibris mirabilis fiat musculus, Lienis cellulas comprimens, quo sanguis per splenicum ramum propellatur non absimili structurâ ac ritu qualis in grandioribus cordis auriculis observatur.'—*Phil. Trans.* vol. vi. p. 2150.

contract upon the venous cells, to empty them, and to prevent the stagnation of the blood in them. This statement of the muscular structure of the trabeculæ, first given by this great anatomist, received numerous supporters since his time, in Leeuwenhock, Stukeley, and others, whilst it was denied by De la Sône, the immortal Haller, and at a later period by Sir Everard Home. More lately Malpighi's assertion has been confirmed by the microscopic examination of many modern physiologists—Sharpey, Kölliker, and others.

The veins of the spleen, which he demonstrated by means of inflation, and then drying the organ, he noticed were large, divested of their external tunics on entering it, and apparently forming dilated venous cavities, separated from each other by membranous septa, formed by the drying up of the pulpy substance supported by the trabeculæ; he supposed also that these septa communicated directly with the veins.

The Malpighian bodies he described as small spheroidal membranous sacs, filled in the natural state with fluid contents, which were suspended from the ends of the small arteries, and were contained in the membranous septa, either projecting from their walls, or contained in the centre of the red substance (subrubra substantia). These small glandular bodies he believed at times burst, discharging their fluid contents, which were poured into the membranous septa, and from thence conveyed into the veins, where, becoming mixed with the blood, they were

supposed to induce chemical changes in this fluid which disassociated its elements, and the proceeds conveyed to the liver assisted materially in the secretion of bile; and this theory was supported not only by anatomy, but by experiments and the researches of chemistry.

The conclusions which this great anatomist arrived at from these minute and laborious researches, were that the spleen contains all the elements of a true gland, and although, unlike other glands, it was unprovided with a duct to carry off the elaborated secretion, he believed that the veins were peculiarly modified to perform this office.

This conclusion, deduced in the true spirit of the Baconian philosophy, was the first clear result given to the world of the complicated structure of this peculiar gland, a conclusion which completely overthrew the mystic and unphilosophical statements of his predecessors, and which was destined, together with his researches in other structures, to mark a new era in the history of physiology.

To nearly the end of this century no considerable progress was made in the anatomy of this gland, its general description by Malpighi being followed by Bidloo[1] and most of the anatomists of his time.

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[1] Bidloo, Godfrey, *Anat. humani corporis.* A.D. 1685. P. Tab. 36. 'Membranarum, vasorum fibrillarumque hæc elegans congeries, cujus extremitates seu expansiones in cellulas vel retia abeunt plurimis exornatur glandulis. Harum glandularum, sive pellucidarum glandulosarum vesicularum infinitus est numerus, figura ovalis, cavitas exigua.' 'Racematim plures, ab unâ propendent vasorum, quæ ipsas obvolvunt, conjugatione.'

At about this period, also, some knowledge of its comparative anatomy was acquired from the investigations of Blasius[1], whilst the demonstration of its vessels by the successful injections of Ruysch, and of the lymphatics and nerves by Nuck[2] and others,[3] served to complete almost the whole of its general anatomy. Tilingius[4] believed that its use was to change the thinner and more watery chyle into blood, and to purify the blood by separating a 'succus crassus, tartareus, et salinus.' Diemerbroeck[5] adopted nearly the same opinion as Malpighi regarding its structure and use, as also did Munnicks,[6] Gibson,[7] and Velthusius;[8] whilst at the same time the two former gave a more minute description of the lymphatic vessels, and described

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1 Gerardi Blasii, *Anatome animalium.* Amstelodami, 1681.

2 Antonio Nuck, *Adenographia curiosa et uteri fœminei anatome nova.* Lugd. Bat., 1692. Pp. 143—4.

3 Diemerbroeck, Munnicks. The former author describes the nerves as supplying the interior of the organ. Gibson and Munnicks describe them in a similar manner.

4 Mat. Tilingius, *Anat. lienis.* Rinthel, 1673.

5 Diemerbroeck (Istrandi de) *Opera omnia anatomica.* Ultrajectum, 1685. Pp. 79—88.

'Materiam subacidam ex sanguine arterioso conficere, e quâ cum sulphuris particulis in hepate rursus mixtâ et specifico modo excoctâ, sanguinis chylique fermentum biliosum conflatur.'

6 Munnicks, Johannes, *De re anatomicâ.* Trajecti ad Rhenum, A.D. 1697. Pp. 48 to 52.

'Hanc equidem constituo sanguinis depurationem a fæcibus terrestribus acido-salinis, atque à bile excrementitiâ in hepate secernendâ et majorem adeo ejusdem perfectionem.'

7 Gibson, Thomas, *The Anatomy of Humane Bodies epitomized.* London, 1694. Pp. 108 to 122.

8 Lambertus Velthusius, *Tractatus med. phys. de liene.* A.D. 1687.

them as arising from the Malpighian glandulæ, an opinion which some physiologists assert even at the present day. Thus Diemerbroeck, in speaking of the lymphatics, says, 'Oriuntur autem ex multis minimis glandulis conglobatis in liene subsistentibus.'

The opinions of Malpighi did not, however, receive universal assent. Thus Mayow[1] absurdly supposed, that the nitro-gaseous particles not used for the animal functions are brought to the spleen by its nerves, and that, being there mixed with the saline sulphureous particles of the blood, they excite effervescence in it, which is fitted to the reducing its saline sulphureous particles to their due volatility. Drelincurtius,[2] who gives an elaborate enumeration of the statements of other authors, concludes that the thick venous blood contained in the veins of the spleen is diluted by the more limpid arterial blood, so that it may reflow more easily into the heart, whilst Dionis[3] believed that the use of the organ was to refine the blood, and purify it before proceeding to the same viscus. Clopton Havers[4] brought forward an hypothesis of its use at about this period, which, as far as I am aware, received no support from his followers.

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[1] JOHANNIS MAYOW, *Opera omnia medico-physica.* Hagæ, 1681. Pp. 342 to 353.

[2] *Disputatio inauguralis anatomica practica de lienosis.* CAROLUS DRELINCURTIUS. Lugd. Batav., 1693.

[3] DIONIS, *L'Anatomie de l'homme.* Troi. edit. Paris, 1696. Pp. 198 to 202.

[4] CLOPTON HAVERS, *Osteologia Nova.* Lond., 1691. Pp. 210 to 215.

His theory was that the spleen served to elaborate the synovial fluid, or mucilage, 'from whence it is administered to the blood, and by that dispensed in its circulation to all the parts, about which it is necessary it should be employed.' And he adds, 'For that it contains and exhibits such a kind of juice, there is no man that has his senses, and examines it, can deny.' The opinions of Malpighi were more strongly opposed, however, by Ruysch,[1] who appears to have been one of the first anatomists who arranged the spleen with the thyroid, supra-renal capsules, and the lymphatic glands, as vascular or blood glands, 'glandulæ sanguineæ,' (glands without ducts;) he also arranged the liver under the same category. The description which he gave of the structure of this organ was entirely different to the philosophical account of Malpighi, and was derived chiefly from the results of his peculiarly successful minute injections. He denied the existence of the trabecular tissue, which had been so carefully and minutely described by Malpighi, believing these bands to be nothing more than blood-vessels and nerves surrounded by a fibrous membrane. He admitted their existence, however, in some of the larger mammals, as in the bullock, and stated that where they existed areolæ were formed by

[1] F. RUYSCH, *De glandulis, fibris, cellulisque lienalibus, Epist. Anat. Quart. Opera omnia.* Amstelodami, 1696. Also FR. RUYSCHII, *Thesaur. Anat.* Amst., 1701. Also F. RUYSCHII, *Observatio anat. chirur., Observatio* 51, p. 67. 'Lien, hepar, renes succenturiati, &c., pro glandulis sanguineis non inepte haberi possunt.'

their complex interlacing. The Malpighian bodies he considered as nothing more than minute capillary vessels, arranged in convolutions, and forming round succulent bodies. He believed the chief mass of the spleen to be a vascular mesh, formed by the ramifications of the artery, vein, lymphatics, and nerves, all of which were surrounded by their peculiar membraneous investment, the capillary vessels being supposed to terminate in the soft succulent substance, the splenic pulp, and to communicate with the lymphatics, which were supposed to convey away the secretion formed from the vessels of this pulp.

These opinions of Ruysch on the structure of the spleen were supported by Craus,[1] who dissents from the statements of Malpighi, regarding the existence of cellules and glands; whilst Palfin,[2] Verheyen,[3] Morgagni,[4] and others, quote the description of both authors, without making any new addition to our knowledge, either of its structure or function.

In the year 1706, Leeuwenhock[5] gave the first account that had at that time appeared of the micro-

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[1] Craus, D. Rudolph Guil., *Disp. inaug. med. de schirro lienis.* Jenæ, Cap. 3., *De lienis structurâ*, pp. 8, 9, 10. 1705.

[2] Palfin, M. Jean, *Anatomie du corps humain. Premiere partie.* Paris, 1726. Pp. 125 to 128.

[3] Philip Verheyen, *Corporis humani anatomiæ*, Lib. i. Bruxelles, 1726. Pp. 85 to 89.

[4] Morgagni, Jo. Baptistæ, *Adversaria anatomica omnia.* 1718, Lugd. Batavorum.

[5] A. V. Leeuwenhock, 'Microscopical Observations on the Structure of the Spleen.' *Phil. Transact.* 1708. Vol. xxv., p. 2305.

scopical structure of the spleen. His observations, however, did not throw much new light on its anatomy, which had been so successfully displayed by his predecessors. He described the fibrous trunks (trabeculæ) as arising from the inner surface of the investing membrane of the organ, and ramifying and anastomosing, till joined by those from the membrane on the opposite side. He stated these bands to be of a fibrous structure, which he believed to be specially endowed with contractility, but maintained that they are not muscular. He described the substance of the spleen to be composed of very small globules or particles, so small that he could not give any figure of them, but considered them as 'depending on' and proceeding out of the small fibrous trunks (trabeculæ), and as occupying the meshes formed by their complex interlacing. No mention is made by him of the Malpighian bodies. The only conjecture which he offers as to the function of this organ is, that, if the blood becomes stagnant in it from the circulation in the liver being impeded, the spleen has the power of propelling it, by the contractility of the fibrous bands, assisted by the diaphragm, which, he says, in inspiration presses upon the surface of the organ.

In 1714, T. Douglass,[1] in a paper in the Philosophical Transactions, has mentioned a case in which numerous 'round whitish bodies, of pretty hard consistence, and abundance of small white and softer

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[1] T. Douglass, 'Observations on the Glands in the Human Spleen.' *Phil. Transact.*, p. 499. Vol. xxix. 1716.

specks, both of which were of the same nature,' were found in the spleen of a human subject, a boy ætat. 5, who had died of consumption, and these bodies were supposed by him to be of the same nature as the glands described at an earlier period by Malpighi.

At about this period the discoveries which had been recently made by some celebrated anatomists (Rudbeck Bartholino and Nuck) of the lymphatic system modified very considerably the account of the function of some parts of the spleen, as described by physiologists; and in the next essay on this organ by Eller,[1] the lymphatic vessels are described by him as being the principal channels through which the secreted products are carried off, although he was not the first anatomist who described these vessels as arising directly from the Malpighian bodies.

His description of the fibrous tunic does not differ in any particular from that of his predecessors; but the trabeculæ are stated by him to be of two kinds: some contain arteries, others nerves: according to him, those trabeculæ which contain nervous filaments are accompanied by minute lymphatic vessels.

In his account of the arteries of the spleen, there is one new fact stated by him which had escaped the sagacity of Ruysch, viz., that the smaller ones terminate in numerous tufts or pencils of capillaries,

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[1] JOHANNE THEODORO ELLER, Anhaltin. *Dissertatio inauguralis de liene.* Lugd. Bat., 1716. In HALLER's *Collect. Dis. Anat.*, vol. iii. There are many theses on the Spleen (its excision by DEISCH, &c.) in Vols. i. iii. iv. vii. in HALLER's *Collect. Dissert. Anat.*

which ultimately becoming invisible, and presenting the appearance of a homogeneous mucus, are continuous with the venous radicles.

He does not describe the veins as in any way peculiar, and believes that the venous cells described by Malpighi are formed solely by their walls being distended, or their rupture by inflation.

The Malpighian bodies, which he states were surrounded by a plexus of blood-vessels, he believed to be cut fibres (abscissæ fibræ); the lymphatic vessels of the spleen he described as arising from the Malpighian bodies and from the extremities of the minute arteries, which accompany the trabeculæ, and being conveyed to the surface of the spleen, poured their contents into the blood of the splenic vein.

An entirely new hypothesis was in the year 1722 put forward by Stukeley[1] in the Gulstonian Lecture delivered by him before the Royal College of Physicians; but his description of its structure differed little from that given by Malpighi and his numerous followers. His account of the fibrous capsule of the organ, the trabecular tissue, and the venous cells, is precisely similar to that given by the Italian anatomist; but he doubts the existence of the glandulæ, and believes that the 'tendons of the trabecular muscles,' or 'glands serving to lubricate those tendons,' or perhaps

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[1] W. Stukeley, *On the Spleen, its Description and History, Use and Diseases*, (being the Gulstonian Lecture for 1722.) Lond. 1723. In folio. (Some details on the comparative anatomy of the spleen are to be found in this work.)

'plexuses of nerves,' had been mistaken for glands. With regard to the functions of the spleen, he imagined that it serves to maintain the balance of the circulation, acting, in fact, as a diverticulum, or safety-valve, to the systemic circulation; an opinion which has not only been entertained by numerous followers since his time, but one which has been proved by experiment and more careful and extended observation. This alternation, however, in the size of the organ, he believed to depend on a slow and periodic contraction of the muscular investing membrane and trabeculæ, the alternate contraction and relaxation of which would serve either to empty or fill the venous cells. Hence he states that where the abdominal vessels are (distended) replete with blood, as in digestion, plethora, menstruation, fevers, &c., the spleen opens its cells and relieves the hyperæmia. When, on the contrary, the balance of the circulation has become restored, and a supply of blood is required, the spleen contracts upon the venous cells, pouring forth the blood contained in them to meet the required demand. This view of its diverticular use was also advocated fifteen years later by Cowper,[1] and received additional confirmation some little time after, from the observations of Lieutaud,[2] who makes mention of the existence of very

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[1] Wm. Cowper, *The Anatomy of Humane Bodies.* Revised and published by Albinus. Leyden, 1737.

[2] Lieutaud, 'Observation sur la grosseur naturelle de la rate.' *Mem. de l'Acad. de Paris.* 1738. Et Lieutaud, *Essais Anatomiques, contenant l'Histoire exacte de toutes les parties qui composent le Corps de l'Homme.* 1742. Pp. 308—15.

considerable variation in its size at different periods, the spleen being small when the stomach is distended, that organ being supposed, when full, to press upon it, but being large when the stomach is empty. The theory which this author proposes of the use of the spleen, is entirely mechanical. He says that the blood, by its retardation in the spleen, will be rendered thicker, and consequently more fit for the secretion of the bile; and that when the stomach is full, it will be pushed towards the liver, which receives more blood during digestion, and separates, consequently, more bile. Richerand[1] also adopted a similar view of its function.

The next description that I find given of the spleen is by Winslow.[2] His account of the trabeculæ differs from that of most anatomists; he describes them as a cottony tissue (tissu cotoneux), 'transparent, and of extreme fineness, which is spread throughout the whole mass of the spleen.' This texture, he considers, surrounds and encloses the splenic vessels, and ultimately forms minute cells, in which the splenic capillaries terminate. These cells, he states, communicate with one another, and are filled with blood extravasated from the capillaries which float in these spaces. The cells were supposed by him to be what Malpighi had described as glandules, or

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[1] Richerand, A., *Elements of Physiology.* 1812.

[2] Winslow, *Exposition Anatomique de la Structure du Corps humain.* Paris, 1732. P. 540. Or Nouvelle Edition, tom. iii., pp. 176 and 337, 339, 346, 348, 349.

follicles containing glandular particles. (Malpighi a regardé ces petites cellules cotonneuses 'comme des capsules particulières ou des follicules, qui renferment autant de petits corps glanduleux.') He describes the existence also of small corpuscules in the spleen of man and animals: in man they are 'visible only with the aid of the microscope;' but in the spleen of oxen, boiled and prepared by a peculiar manipulation, they are easily seen, from their large size; they are also firmer, and collapse when injured. He states that these grains are attached to the end of the 'extreme arterial branches,' similar to a bunch of grapes. From each of these he has traced two small tubes going out of each corpuscle, and lost in the sides of the spleen. The use which he assigns to this organ, is that it serves with the omentum, appendices epiploicæ, and mesentery, as auxiliary to the formation of the bile, producing changes on the venous blood traversing it, which, being mechanically retarded in it, would acquire some peculiar property from the action of the splenic nerves. Meslon,[1] also about the same period, believed that it assisted in the secretion of the bile, by diluting the thicker blood brought from the intestines to the liver, with the thinner blood of the splenic vein; an opinion which was advocated by Heister[2] and Cowper, the latter also adopting its diverticular function.

Among the many various attempts that about this

[1] J. D. Meslon, *De liene.* Lyons, A.D. 1738.

[2] Laurence Heister, M.D. *Compendium of Anatomy.* 1752.

time were made to determine the function of the organ, that of excision was practised, by Deisch,[1] but no positive results were obtained from them. Pohlius,[2] also, on the other hand, who observed its absence in the human subject in one case, could not discover that the functions of the body were disturbed.

The best memoir that appeared soon after this time, was by De La Sône,[3] in the *Histoire de l'Academie de Paris* for 1754, which contains much original observation on the anatomy of the spleen.

In it he denied the muscularity of the fibrous capsule and trabeculæ, but agreed with Malpighi as regards their arrangement, and stated that they are distinctly ligamentous in texture. The sheaths of the vessels he believed not to exist in man and those animals where the arteries enter by subdivided branches, but only in those animals (bullocks, sheep, &c.) in which the arteries entered by single trunks.

With regard to the vessels themselves, he gives a very accurate description. He doubts the great vascularity of the spleen as described by Ruysch, and describes the arteries at their ultimate ramification, piercing the network of the trabeculæ in every direction; their ultimate ramifications degenerating

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[1] DEISCH, M. P., *Dissertatio inauguralis de splene canibus exciso.* Halæ, 1735.

[2] POHLII, J. C., *Programma de defectu lienis, et de liene in genere.* Lipsiæ, 1740.

[3] DE LA SÔNE, 'Sur la rate; ou, histoire anatomique de la rate. Premier Mémoire.' Part 1st., *Histoire de l'Academie Royale des Sciences de Paris,* for 1754.

into a substance of consistence as delicate as brain, and appearing, when washed with water, like a pulpy cotton, with sometimes red globules distinguished in it. The venous cells which had been described by Malpighi, he demonstrated by inflation and desiccation; but he denies that they have membranous walls, believing that the pulp forms the walls of the cells, which appear membranous simply by the process used in their demonstration. The Malpighian glandules he does not appear to have distinguished, for he merely quotes that author's account of the sacculi, and apparently confounds them with the pulp, as he concludes that glandular and follicular grains compose the pulpy part of the spleen. The description of the spleen given by the immortal Haller,[1] does not contain much original matter. He denies the muscularity of the fibrous tunic and trabeculæ, an important statement from an authority so high; and with regard to the structure of the other parts of the organ, does not differ much from his predecessors. The use to which he assigns the organ, is that it prepares the blood for the liver.

The valuable and interesting researches made by Hewson[2] at this time, served to change the opinions previously entertained of the use of the spleen. The

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1 Haller, *Elementa Physiologiæ*. Vol. vi., Pp. 385—426, Liber xxi., *De Liene*.

2 Hewson, Chap. IV. 'On the Spleen,' and V. 'On the Manner in which the red particles of the blood are formed.' *Experimental Enquiries*. Part iii. Published by Falconer, in 1777. Ed. Syden. Society of 1846. Pp. 264, 268.

general anatomy of the organ he described with great care and minuteness, and from its great vascular supplies, he inferred its glandular nature, referring it to the lymphatic system, and classing it with the ductless glands (thyroid and thymus.) The use to which he assigns the organ is that of converting the lymph into blood globules: the lymph particles formed in the lymphatic glands and thymus, he believes are carried with the blood to the spleen, which, he says, 'has the power of separating them from the other parts of the blood, and depositing them in the cells above mentioned,' where the arteries, arranged as a network on the cell wall, secrete from the blood the vesicular portion around these lymph particles, which thus forming the red corpuscles, are absorbed by the lymphatics which originate in these cells, convey them to the thoracic duct, and so into the blood-vessels. That the function of the spleen was such as he described, he believed proved by the analogy of the spleen to the lymphatic and the other vascular glands; by the large number of lymphatics which he supposed to act as excretory ducts; by observing the absence of central particles or lymph globules in the splenic vein; by experiments which showed that the lymph in the splenic lymphatics is reddish, from the presence of a large number of red blood particles, and is peculiarly coagulable, and by the incoagulability of splenic venous blood, which arises from the lymph being employed in the formation of the red blood globule. These opinions of Hewson's, although for some time neglected, have received support of later years from the researches of

other physiologists,—Tiedemann and Gmelin, Schultz and Donne.

Soon after this period, the elaborate and original thesis of Assolant[1] appeared, an essay remarkable for the research and labour displayed in its production. The observations made by this anatomist, in which he was assisted by the celebrated Dupuytren, were chiefly confined to the elucidation of the structure of the organ, and more particularly its vessels. His most important contributions were his observations on the circulation in the organ. He found that when liquid or air was thrown into one arterial branch, it does not pass into the branches of the others; and a similar arrangement he found in the veins; if also in a living animal, one division of the splenic artery be tied, the part of the organ to which it is distributed becomes gangrenous, the rest remaining healthy. From this he concluded that the blood-vessels of the organ supplied particular compartments which have no communication together by anastomoses. The Malpighian glands he describes very accurately as far as their outward form, as 'from one-fifth of a line to one line in size, mostly round, sometimes angular, attached to the surrounding tissue, and provided with a small number of vessels, occurring sometimes close together, sometimes scattered: they have no cavity in their interior, and do not effuse any liquid when punctured or cut.' Assisted by Dupuytren, he also excised the organ in a large number of dogs, but he

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[1] *Thèse de* M. Assolant. Paris, 1801.

failed to arrive at any conclusions from these or his other researches, concerning the use of the organ, and expresses very considerable disappointment at his failure.

The views which Stukeley entertained regarding the use of the spleen received some confirmation about this period from the researches of the Italian anatomist Moreschi,[1] whose observations were chiefly confined to the disposition of the vessels of the organ, the use of which he believed was to act as a reservoir and regulator of the circulation in the stomach, the arterial blood supplying that organ during the process of digestion, the venous blood being supposed to augment the fluidity of the portal blood conveyed to the liver. The immortal Cuvier[2] attempted to elucidate the function of the spleen by the aid of comparative anatomy, he being the first author who treated to any extent of the structure of this organ in animals. He indirectly states the spleen to have two functions. 'Thus the spleen has on the one hand some immedidiate relation with the secretion of the bile, and on the other, some indirect relation with that of the digestive juices, or of the commencement of the intestinal canal.' These functions he deduced more particularly from consideration of the arrangement of the vessels of the organ. In the oviparous vertebrata he observes, that the arteries of the spleen

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[1] D. Moreschi, *Del vero è primario uso della Milza.* Milan, 1803. And *Comm. de Urethræ Struct., accedit de Vasor. Splenicor. in animal. constitut.* Milan, 1817.

[2] Cuvier, *Anatomie Comparée.* Tom. iv. pp. 56 to 68.

being derived from those which supply the stomach, or commencement of the intestinal canal, there result certain relations in the distribution of blood to these different viscera, probably of great importance with reference to the function of the spleen; so that the easier the access of the blood to the spleen, the more difficult is it to the arteries immediately in relation with it; consequently, the more blood will the spleen turn to its own purposes, and the less abundant will be the gastric juice; whilst on the other hand, these conditions will be reversed, when the access of the blood to the stomach is easier, and that to the spleen more difficult. It was from these facts that he deduced one of the functions of this organ to be that of having some indirect relation with the secretion of the gastric juices, whilst the fact of the splenic vein forming in many animals the most important branch of the vena portæ, led him to believe that it had some immediate relation with the secretion of the bile. Cuvier's theory was adopted by Sprengel,[1] who had made similar observations regarding the position of the viscus with the other organs in animals. 'Pariter igitur cum secretione ventriculi ac cum hepatis functione nectitur id viscus.'

The elder Caldani[2] not only advocates a similar opinion, but considers more minutely the method by which it is possible that the spleen may assist in

[1] C. Sprengel, *Institutiones Medicæ.* Tom. i. Amstelodami, 1810. Pp. 358—360.

[2] L. M. A. Caldani. Brisciæ, 1807. Vol. ii., part 2. P. 66.

promoting the separation of the bile; either he says by furnishing the materials of the secretion in its own blood, or by diluting with its blood that ascending into the liver by the mesenteric vein, and which is loaded with oil derived from the viscera, and so might possibly be retarded in the vena portæ; or lastly, by mixing with the bile principles of an alkaline nature generated principally from the vapour of the abdomen. 'L'uso della milza sembra esser quello di servire alla separazione e di promoverla; si perchè dia materia col suo sangue a una piu abbondante separazione; si perchè con questo medesimo sangue quasi arterioso diluisca quello, che per la vena mesenterica ascende nel fegato; il quale pieno d'olio somministrato dalle viscere pingui facilmente si ritarderebbe dentro la vena porta; sì finalmente perchè frammischj colla bile principi di natura alcalina generati principalmente dal vapore dell' abdomine.'

About the year 1817, Heusinger[1] investigated with considerable assiduity the nature of the Malpighian glandulæ; he describes them as whitish bodies, occasionally small, occasionally dilated, disappearing on the inflation of the splenic vein, but re-appearing on making an incision through the part. This phenomenon, together with the results obtained by injection, led him to infer that these bodies are vesicles or

[1] HEUSINGER, C. H., *Ueber d. Bau und der Verrichtung der Milz.* Thionville, 1817. See notice of, in *Ed. Med. Surg. Jour.* Vol. xviii. pp. 279—295, 1822.

minute glands, abundantly supplied with blood-vessels, and liable to occasional dilatation, and which when filled by mutual compression, assume the hexagonal figure. . . .

Dr. Hopfengaertner,[1] in his inaugural dissertation, admitted the general accuracy of Heusinger's observations, but thought his statement to be incorrect in considering these bodies as separate glands, for he found them to be globular and separate only on the surface of the spleen, whilst in the interior of the organ, they appear as convolutions (gyri) or cylindrical turnings. The further observations of this anatomist led him to believe that the great mass of the spleen consists of what he calls the proper substance (pulp) which is soft and fluid, but the structure of which is not considered. He states that this may be injected either by the arteries, veins, or lymphatics, but that the direct passage of minute arteries into venous radicles, can nowhere be demonstrated.

The results of the investigations of Sir Everard Home[2] are published in the Transactions of the Royal Society for the years 1808, 1811, and 1821.

In his first papers (1808) he has attempted to show that the spleen is the organ through which fluids are conveyed after absorption, from the cardiac portion

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[1] C. F. Hopfengaertner, *Diss. hist. annot. ad structuram lienis*, in 4to. Tübingen, 1821.

[2] Sir Everard Home, 'On the Structure and Uses of the Spleen.' *Phil. Trans.* 1808. 'Further Explanations on the Spleen.' *Phil. Trans.* 1808.

of the stomach, without passing into the intestines. He describes the glands of Malpighi 'as distinct cells, having a cavity in their interior, containing a fluid which escapes when the cells are punctured, and renders their membranous coat visible, so that it would appear that their distension is connected with the state of the stomach, and therefore only takes place occasionally, and that the elastic capsule, by which the spleen is surrounded, adapts the organ to these changes in its volume.' He observed that after injection of fluids into the stomach (the pylorus being tied) the spleen became turgid, and that the Malpighian cells were particularly large and distinct, and although it is stated by him that the lymphatic vessels were not visible, he concluded that liquids were carried by this organ into the circulation, though by what means he has not mentioned. When, on the other hand, animals have been kept without fluid for several days, the organ is contracted, and the Malpighian bodies only distinct when seen through a magnifying glass. In 1811[1] he renounced these opinions, on finding that fluids were absorbed with equal rapidity after extirpation of the organ, but believes that 'the fluid contained in the cells of the spleen is secreted there,' during the process of digestion; whilst from the large size of the lymphatic

[1] Sir Everard Home, 'Experiments to prove that Fluids pass directly from the Stomach into the circulation, and from thence into the cells of the Spleen, the Gall Bladder, and Urinary bladder, without going through the thoracic duct.' 1811. *Phil. Trans.* P. 163.

vessels, he believes them to be the excretory ducts, destined to carry off the secretion found in these cells, an opinion similar to that of Hewson's.

His latest observations are contained in the Croonian lecture delivered in 1821.[1] He here describes the structure of the spleen as consisting of 'blood-vessels, between which there is no cellular membrane, and the interstices are filled with serum and the colouring matter of the blood from the lateral orifices in the veins, when these vessels are in a distended state; which serum is afterwards removed by the numberless absorbents belonging to the organ, and carried into the thoracic duct by a very large absorbent trunk.' He describes the formation of the glandulæ Malpighi in the following manner.[1] 'The lymph globules carry along with them into the interstices carbonic acid gas, and the mucus, soluble in water, in great abundance; but no blood globules, since none are found in the cells. As soon as the lymph is at rest, the carbonic acid gas being let loose, forms the cells that surround the lymph globules, the sides of which are held together by the mucus, putting on the appearance of corpuscules without colour, and are thus mistaken for glands; the gas is absorbed by the blood in the arteries and veins.' The spleen, from this mechanism, appears to be a reservoir for the superabundant serum, lymph globules, soluble mucus, and colouring matter, carried into the circulation immediately after the process of diges-

[1] Sir Everard Home, *Croonian Lecture on the Structure of the Spleen, &c.* 1821. P. 38.

tion is completed. These observations complete those made by this distinguished surgeon, but they do not add much to our knowledge of the structure or function of this complicated organ.

Treviranus,[1] on the supposition that the lymph is transmitted from all directions to the centre by the areolar tissue, conceived from the contracted and empty condition of the lymphatics, observed in the experiments of Home, that 'fluids were transmitted from the stomach to the spleen by the cellular tissue,' which after having undergone some change in the Malpighian bodies, are returned into the splenic veins and assimilated into blood—grouping together the thymus, thyroid, and supra-renal capsules with the spleen, as conglobate glands of this system of absorption, and similarly assimilating the lymph carried to them from various parts.

At about the same period with Home's researches in England, Beclard[2] in France brought forward the opinion that the spleen was composed of erectile tissue, similar to the corpus spongiosum of the urethra and other parts; but this statement was made, more from the apparent analogy between them, than from their actual structure being found identical. The erection of the organ also in certain states he believes similar to that of the cavernous body. These observations would have been of the highest import if the splenic

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[1] TREVIRANUS, *Biologie oder Philosophie.* 1814. Vol. iv., pp. 525—530.

[2] P. A. BECLARD, *Additions à l'anatomie générale de Xavier Bichat, pour servir de complément aux éditions en quatre volumes.*

vessels had been fonnd identical in arrangement with those of erectile organs, but the want of such knowledge only led to a classification purely hypothetical.

Professors Tiedemann[1] and Gmelin, in Germany, at the same time with Home and Beclard, were also investigating with peculiar zeal the function of the spleen, and the conclusions to which they arrived were very similar to the researches of Hewson. The results of their experiments and inquiries were:—

1st. That the spleen was an organ closely connected with the lymphatic system. This was inferred from the co-existence of the spleen and the lymphatic system in the vertebrate classes, as well as from the large size of the organ in those animals which possess the largest number of lymphatic glands, from its possessing also a large number of lymphatic vessels, and in the construction of the organ bearing some relation to the lymphatic glands, and, lastly, from the fact that in the turtle, the absorbents of the small intestines pass to the spleen, and, continuing their course, again emerge from the organ and proceed to the thoracic duct.

They believed in the second place, 'That the spleen secreted a coagulating fluid from the arterial blood, which is taken up by the absorbents, and conveyed to the thoracic duct.' This they inferred from the reddish colour of the lymph in the lymphatic vessels, from the large size of the artery, which may be compared to that of any organ in

[1] TIEDEMANN et GMELIN, *Sur l'absorption.* 1821.

which a copious secretion takes place, and which is much larger than the nutrition of the organ requires, and, lastly, from the ready communication between the arteries and the lymphatics, by which means some part of the arterial blood reaches them. They stated, lastly, that this 'fluid, when poured into the thoracic duct, is intended to make the chyle resemble the mass of blood.' This they endeavoured to prove by examining the lymph in the thoracic duct of a dog from which they had previously excised the spleen, when they found a very small portion of crassamentum, with an abundant quantity of serum, of a pale red colour, which had never been observed before in their prior experiments on healthy dogs, the crassamentum being in all their former experiments in much larger quantity.

Dr. Hodgkin[1] revived the opinion brought forward by Stukeley that the spleen 'performs in the animal system a similar office to that which tubes and valves of safety do in various kinds of chemical and mechanical apparatus,' tending to obviate any inconvenience which might arise from a sudden disturbance between the balance of the vascular system and the fluids circulating in it. These opinions he deduced from the peculiar structure of the organ, its situation as admirably adapted for any change in its dimensions, its peculiar relation with the abdominal viscera, through the vena portæ acting as a safety valve on that

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[1] HODGKIN, 'On the Uses of the Spleen.' *Ed. Med. and Surg. Jour.* Vol. xviii., pp. 83—91. 1822.

system, which, probably on this account chiefly, has not been furnished with valves; its variation in size concurrent with a full or empty state of the vascular system; its peculiar state in certain diseased conditions of the system, and lastly, from the results of Home's experiments which have been already considered. It was from those numerous facts that he concluded 'that the spleen is to maintain the balance between the circulating fluid and the vessels destined to contain it.'

Among the many speculations regarding the structure and use of the spleen, that of M. Julio Arthaud[1] is peculiar in his referring it to the nervous system, believing it to be 'a plexus of nerves connected with the visceral ganglia,' and that the organ was an electrical apparatus.

The experiments of Dr. Dobson[2] at this period threw much additional light on the function of the spleen. He observed that during the digestive process, this organ became of a very considerable size, its volume increasing from the third hour after eating up to the fifth, when it arrived at its maximum, gradually decreasing in size after that period. In the next place, in dogs whose spleen had been excised, no inconvenience was produced except during the digestive process, when, four hours after a full meal, symp-

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1 'Sur l'organisation de la rate,' par M. J. ARTHAUD. In *Journal des progrès des sciences médicales.* 1827. P. 216.

2 WILLIAM DOBSON, *An Experimental Inquiry into the Structure and Functions of the Spleen.* 1830. Noticed in *London Med. and Phys. Journal*, Oct. 30, 1830.

toms of plethora were manifest. Lastly, by injecting blood into the jugular vein the spleen was observed to enlarge considerably, whilst on the contrary it diminished in size when blood was withdrawn from the vein. From these data he concludes 'That the spleen acts as a reservoir for containing the additional quantity of blood which the vascular system has received by means of the nutritive process.'

Dr. Hake,[1] whose observations on the structure of the spleen are to be found in the proceedings of the Royal Society, suggests the idea of this organ being a diverticulum for venous blood.

In the description given by Müller,[2] there is considerable advance made in our knowledge of the spleen. He admits the existence of a fibrous trabecular tissue, and has demonstrated by means of injections the arrangement of the blood-vessels. The minute branches of the arteries, he believes, are chiefly distributed to the pulp, whilst to the sheath of the larger vessels the corpuscules are attached, some of the smaller branches passing superficially over their walls, but not distributed to them. He describes the veins as a plexus of venous canals, of considerable size, which appear scarcely to have any distinct coats. He also observes that the pulp is pierced by numerous

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[1] T. G. Hake, M.D., 'On the Structure and Functions of the Spleen.' *Proceedings of the Royal Society, June* 20, 1839. *No.* 39.

[2] Müller's *Physiology*. Translated by Baly. Second ed., vol. ii., Pp. 616—621. 'Ueber die Structur der Eigenthümlichen Körperchen in der Milz einiger pflanzenfressender Säugethiere.'—Müll. *Archiv.* 1834.

foramina, which he calls venous canals, which, when inflated, present a resemblance to the corpora cavernosa penis. He denies, however, the existence of true cells in the spleen. The most important addition, however, which he has made to the anatomy of this organ, is in his account of the glandulæ Malpighi. At first he described them as of two kinds: 1st. Round whitish bodies, devoid of internal cavity, very soft and very vascular, which are sometimes found in the dog and cat, and rarely in the human subject. 2nd. Round white bodies found in the spleen of the herbivora. These are the bodies Müller believed to be the true Malpighian corpuscules. They are circumscribed, firm in texture, of a whitish grey tint, with a distinct cavity containing a white pulpy matter, consisting of 'irregular globular particles,' of about the same diameter as the red particles of the blood, though not flattened like them, resembling somewhat the granules of the pulp. These bodies are connected to the sheaths of the splenic arteries. Subsequently, however, Müller describes the smaller arterial branches partly to continue on the side of the corpuscules without giving off branches to them, partly to perforate either a portion or the whole of the corpuscule, never giving any branches to the interior, they continue on their coats and then quit them; on their emerging they divide into a pencil-shaped mass of ramifications, from which the commencement of the veins spring, scarcely having as yet a special coat. 'If the pulp of the spleen be carefully examined, it will be seen that it is as if cribriform, and constitutes,

as it were, a network of red partitions, the diameters of which are larger than the interspaces and canals existing between them. It is these venous canals that give the cellular appearance seen in inflation of the veins of the pulp, and which, indeed, form structures resembling the corpora cavernosa of the penis. Special cells or cavities do not exist.' These observations were made only on the ox and pig.

The pulp consists of a mass of red brown granules, globular in form, and about the same size as the red blood globules, but not flattened like them. In this granular mass the capillary vessels are distributed. He considers the function of the organ to be that of producing some change in the blood circulating through it, or in the secretion of a lymph of peculiar nature, which tends to perfect the formation of the chyle.

Most of these views, but in a more or less modified form, received confirmation from the investigations of Giesker,[1] who believes that the organ has some connection with the lymphatic system.

We have now arrived at a period when the elder school of anatomy had almost exhausted its task of displaying the general anatomy of the human body; these investigations, however, were of the very highest importance, for they not only were the means of completely eradicating the unphilosophi-

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[1] GIESKER, *Splenologie oder Anat. Physiol. Untersuchungen ueber die Milz des Menschen.* Zurich, 1835.

cal notions of the ancients, but they served to place the science of physiology on a more secure foundation, and, what is of infinitely more importance, materially to aid in the diagnosis and treatment of disease.

Between that period and our own, vast alterations have taken place in the sciences of anatomy and physiology. The study of relative position and form, which had been the almost exclusive task of the elder school, was now thought to be of comparatively slight importance, whilst the intimate composition of all the organs was investigated with unparalleled zeal and singular success. These more minute investigations on some of the points connected with cell growth were first made in the year 1837, by Henle, who demonstrated the growth of the elementary epithelial particles. Similar observations were also made by Turpin and Purkinje. The researches of Dumortier, on the development of the ova of snails, and the embryological researches of Valentin, formed the groundwork of facts for that great law of cell growth which soon after made its appearance. To these first fruits of structural anatomy were soon after added the researches of Schleiden, Mirbel, and Meyen, into the mode of development of vegetable cells; and many instances of the resemblance in form between the animal and vegetable tissues were repeatedly noticed. No result, however, was obtained from these comparisons until the final announcement of Schwann's theory of cell development and cell growth, a discovery which may fairly be ranked as

among the most important of all that have contributed to the advancement of physiology. No sooner were the facts which he had observed, and the laws he had deduced from them, fully known, than a great impulse in the cultivation of structural anatomy took place, the researches into which were now not confined to outward form and position, but extended with scrutinizing and inquiring gaze into the structure of the ultimate tissues of parts, and the laws which govern their development, growth, and decay. These investigations were much assisted, at a somewhat later period, by the aid of organic chemistry, a science which, especially in recent times, has aided considerably in the elucidation of the most abstruse physiological problems—problems which without this assistance the mere anatomist never could have solved. In this department Liebig and Simon stand unrivalled.

Coincident with this great advancement of knowledge, it may easily be conceived that the glandular organs underwent no inconsiderable research and investigation, the general character of these parts was soon made out, and our knowledge of their structure and function carefully displayed, by Bischoff and Berres, in Germany, and in our own country by Bowman, Goodsir, and Dr. Todd. It is only, however, within the last few years, that the anatomy and physiology of the ductless glands has been more carefully examined, and their function attempted to be displayed in the cautious spirit of philosophical generalization.

The accurate Purkinje[1] notices the peculiar corpuscules of which they are composed, and suggests some probable relation of these with the development of the blood or lymph; whilst Henle[2] describes them as composed of a mass of nuclei and cells, the structure of which is similar in all the blood glands. Burdach,[3] about the same period, although describing its anatomy imperfectly, suggests a new theory of the use of the organ. It serves, he says, in the work of plasticity; it also renders the blood more highly venous, which ought in consequence to be more appropriate for the production of the bile, whilst the blood in the branches of the splenic artery going to the stomach is more highly oxygenated, and more proper for its acid secretion; so that there would be between the spleen and the stomach an antagonism, partaken of by the blood, which is divided into two portions, endowed with different qualities.

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1 PURKINJE, *Im Berichte der Versamml. d. Naturforscher zu Prag*, 1837.

2 HENLE, *Allgemeine Anatomie.* Leipzig, 1841.

3 G. F. BURDACH. Paris, 1841. Traduit de l'Allemand. Vol. ix. Pp. 583, 584, 585.—'Il est clair que la rate sert à l'œuvre de la plasticité.' 'Cependant nous voyons dans la rate une organisation qui ralentit le cours du sang, retient plus long temps ce liquide dans les racines des veines, le rend par consequent veineux à un degré plus prononcé, et doit en conséquence l'approprier davantage à la production de la bile.'

'Peut-être les branches de l'artère splenique qui vont à l'estomac fournissent elles à ce dernier viscère un sang plus oxygéné et plus propre à sa secretion acide, de telle sort qu'il y aurait, entre la rate et l'estomac, une antagonisme qui partagerait le liquide sanguin en deux portions douées de qualités différentes.'

About this period, M. Bourgery,[1] in Paris, and Dr. Evans, in this country, were investigating, with great assiduity, the structure of the spleen. The observations of the former are contained in a memoir (since published) presented to the Academy of Sciences at Paris. He describes the organ as presenting two essential elements: 1st, 'The vesicular apparatus,' that is, the hollow communicating venous cavities filled with air; 2nd, 'the intervesicular or glandular apparatus,' or the proper substance of the spleen which forms the partitions between these vesicles.

The vesicular apparatus he supposes to be the secreting portion of the organ, its granular walls and the Malpighian bodies contained in its cavity secreting a fluid which is mixed with the venous blood, and which, after undergoing certain changes, is absorbed by the lymphatics on the walls of the vesicles, and conveyed into the intervesicular structure. The splenic secretion is conveyed away from this structure out of the organ by means of the lymphatic vessels, contributing in this manner to hæmatosis, the impure venous blood going to the liver to furnish bile.

In 1844 Dr. Julian Evans[2] published the results of his Microscopic Observations on the Anatomy of the Spleen in Man and Mammalia. Many of his observa-

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[1] *Anatomie Microscopique de la rate dans l'homme et les mammifères.* Par J. M. Bourgery. Lu à l'Academie des Sciences, Juin 1842. Publié à Paris, 1843.

[2] W. Julian Evans, *Microscopic Anatomy of the Spleen in Man and Mammalia.* Read before the Royal Society. 1844. *Lancet,* Vol. i. 1844. Pp. 63—67.

tions are original, and make an important addition to our knowledge of the structure of this gland. He describes the external tunic and trabeculæ as fibrous in their structure, denying their muscularity. He believes in the existence of the venous cells described by Malpighi, and says they are 'formed of a framework or skeleton of fibro-elastic tissue, and a membrane spread over it, filling up the framework, and lining the cavity of the cell. This membrane is a continuation of the lining membrane of the vein. The cells communicate with each other and with the splenic vein and its branches by means of oval or circular foramina.' There is also, according to this observer, a communication between the cells and the small veins, which return the blood from the capillaries of the organ. The cellated structure of the spleen is nothing more than a 'multilocular reservoir,' capable, by its distension, of relieving the abdominal venous circulation. The contents of the cells and of the splenic vein consist of blood only. The splenic pulp consists of two elements—'the liquor lienis, or splenic blood,' and a cottony substance. The former is an unctuous fluid of a reddish brown colour, containing blood corpuscules, and nucleated particles similar to those found in the lymphatic glands. The cottony substance consists of capillary vessels and of a number of corpuscules, smaller than blood particles, which he calls the splenic corpuscules, and apparently from these arise transparent vessels, more minute than the corpuscules themselves, which the author believes to be lymphatic vessels; these enter the Malpighian

glands, from which, after numerous convolutions, they emerge larger in size, and accompany the arteriole supplying the gland. It is in this manner, this observer believes, that the deep set of lymphatics originate. The Malpighian bodies he concludes to be lymphatic glands. In his description of the splenic artery he notices the fact of its subdivisions supplying only separate portions of the organ, not communicating with the remaining ones, and describes it as terminating in three sets of arterioles. The first set penetrate the Malpighian glands, and emerge in long pencillated tufts, which are lost in the capillaries of the parenchyma; the second supply the parietes of the splenic cells; the third set terminate in the cells by a club-shaped extremity, from which minute capillaries spring. The author concludes, from these observations, that the spleen is a double organ, performing two sets of functions—the cellated structure being considered as a multilocular reservoir, capable of great distension, receiving blood from the veins of the interior of the organ, and transmitting it onward to the vena portæ, and acting as a reservoir for the venous abdominal circulation. The office of the parenchymatous portion appearing to be that of separating a fluid from the blood, which, after undergoing some change in the Malpighian glands, escapes by the efferent vessels, and enters the splenic lymphatic glands.

From this period up to the present time, there has been still great diversity of opinion regarding the structure, and more particularly the function of this

complicated gland. The extensive and accurate researches of Oesterlen,[1] not only on this, but on the allied glands, have added considerably to our previous knowledge. He believes that the peculiar office of the blood glands is to give up to the blood, at certain times and under certain conditions, its more plastic elements, by a dissolution of its nuclei, which he asserts are solidified proteine compounds. Simon,[2] in his admirable essay on the thymus gland, adopts a somewhat similar view; at the same time he considers, with Dobson, that it acts as a safety valve to the general circulation. 'And thus,' he says, I 'would suggest, while the spleen serves mechanically as a diverticulum to the replenished systemic circulation, holding much blood only where much is in temporary excess, so likewise it may withdraw from this lingering blood some of its more plastic elements, and retain them for a time within its own interstitial chambers, a readier, a more quickly available, though scantier sinking fund of nourishment than is afforded in the adipose tissue.' Sanders[3] also adopts a somewhat similar view.

Since the period when Oesterlen and his followers attributed to the spleen the office of a sinking-fund for nourishment, which, under certain conditions, was restored again to the blood, other theories have been adopted, which serve to place the spleen in close

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1 F. Oesterlen, *Beiträge zur Physiologie.* Jena, 1843. P. 41.

2 Simon, *A Physiological Essay on the Thymus Gland.* 1845. Pp. 86—99.

3 W. R. Sanders, M.D., *On the Structure of the Spleen. Annals of Anatomy and Physiology.* By John Goodsir. Feb. 1850. P. 49.

relation with the life of the blood. Kölliker,[1] in 1847, founded the conjecture that the blood corpuscules undergo dissolution in the spleen, and that their colouring matter is employed in preparing the colouring matter of the bile; and this theory he deduced from his observations made on the minute structure of the organ, which showed blood globules, either single or in masses, contained in cells undergoing transformation into dark granules, observations which had been previously made by Oesterlen,[2] Remak, and Handfield Jones,[3] but which presented to them a different signification. The observations of Beclard[4] the following year, that the blood of the splenic vein contains less blood globules than that of other veins, gave rise to a similar opinion of its function; whilst the more minute researches of Dr. Otto Funke[5] on the returning blood from the spleen, led him to adopt no conclusion as to its function, excepting that it contains *more* blood globules than that which enters the gland. The investigations also of Virchow,[6]

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[1] Kölliker, *Todd's Encyclopædia*, June 1849, and *Mittheilungen der naturforschenden Gesellschaft in Zurich.* 1847. P. 120.

[2] Loc. cit.

[3] H. Jones, *Med. Gazette*, 1847. P. 140—2.

[4] Beclard, Dr. J., *Archives Générales de Medicine. Recherches Experimentales sur les fonctions de la Rate et sur les celles de la Veine Porte.* Oct., Nov., and Dec. 1848.

[5] Dr. Otto Funke, *Ueber das Milzvenenblut Zeitschrift für Rationelle Medicin.* Heidelberg. 1851. P. 172—218.

[6] Virchow. This author does not believe in the origin of cells around heaps of blood corpuscules, although he does not doubt the fact of the dissolution of the corpuscules.

(*Archiv. für Pathologische Anatomie und Klinische Medicin.*,

Landis,[1] Gunsburg,[2] and more lately, of Ecker,[3] gave additional support to Kölliker's theory. On the opposite side, Gerlach[4] has revived the theory of Hewson, that the spleen is the place of formation of the blood corpuscules. He explains the formation of coloured corpuscules within colourless ones the reverse way to Kölliker, supposing the cells with golden yellow granules as the younger, and those with unchanged blood corpuscules the elder; that is, that they are those in which the blood corpuscules have completely developed themselves, and from which they are ready to be expelled or set free. These he believes are formed in the Malpighian corpuscules, which are said by him to communicate with the lymphatics, and so are admitted into the current of the circulation. This theory had been adopted somewhat earlier, by Spring,[5] and Poelmann,[6] but was supposed to be more clearly explained by the later observations of

Band i. Ss. 452, 483. *Archiv. für Pathol. Anat. und Physiol.* Band i. pp. 286, 452.)

1 LANDIS, *Beiträge zur Lehre über die Verrichtungen der Milz.* Zurich, 1847.

2 GUNSBURG, *Archiv. für Anatomie Physiologie und Wissenchaftliche Medicin.* Berlin. 1850.

3 ECKER, A., *Handwörterbuch der Physiologie.* P. 130. Art. Milz. 1849.

4 GERLACH, Dr., *Ueber die Blutkörperchenhaltenden Zellen der Milz. Zeitschrift für Rationelle Medizin.* 1849.

5 SPRING. *Mem. sur les corpuscules de la Rate;* in *Mem. de la Societé Royale des Sciences de Liege.* Tom. i. p. 124.

6 CH. POELMANN, *Mem. sur la Structure et les Fonctions de la Rate,* in *Annales et Bulletin de la Société de Médicin de Gand.* Dec. 1846. P. 267.

Gerlach and Schaffner,[1] who conclude that the spleen is the organ in which the formation of the blood corpuscules occurs during extra-uterine life, as the liver is during intra-uterine life, a theory directly opposite to that of Kölliker, Ecker, Beclard, and their followers. Dr. Bennett[2] adopts a somewhat similar view, believing that the spleen, as well as the other lymph glands, are secretors of the blood. Such are the various conflicting opinions of the use of this complicated gland that have been given by physiologists from the earliest period up the present time. These I have detailed from a desire to do all possible justice to those whose labours have served to accumulate our present knowledge upon this point, as well as by a mere retrospective allusion to avoid historical digression and needless discussion upon any new propositions that I may advance in the difficult investigation that I shall now commence.

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[1] Dr. Schaffner, *Zur Histologie der Schildruse und Thymus*, P. 340. *Zur Kenntniss der Malpighischen Korperchen der Milz, und ihres Inhalts.* P. 345, in *Zeitschrift für Rationelle Medizin*, 1849.

[2] Bennett, John Hughes, M.D., *Monthly Journal of Medical Science.* March, 1852.

PART II.

DEVELOPMENT OF THE SPLEEN.[1]

IN investigating the structure and function of any organ, it appears to be of the greatest importance to trace out, in the first instance, its evolution, to observe the parts or organs from which it springs, and, what is even of still greater moment, to investigate the development of the several elements of which the organ consists in its mature state. By these means we are often materially assisted in elucidating the structure, or in deducing the function of a particular organ. For these reasons, I shall commence by describing the development of the spleen, and the several elementary tissues of which it is composed, a part of its anatomy hitherto almost entirely neglected. These investigations have been chiefly conducted on more than one hundred dissections of the embryo chick, and, as far as I have been able to ascertain, the same process is followed out in man and other animals.

About the 72nd hour of incubation I found, in the embryo of the chick, that the vitelline sac had (*already*) sufficiently contracted to form two canals,

[1] For some investigations on the development of the spleen and the other ductless glands, the reader may refer to a paper of the author's in the *Philosophical Transactions* for 1852, p. 295.

of which the posterior was small, but the anterior one was much larger and longer, and took a somewhat tortuous course through the body of the embryo. No trace of either pancreas or spleen was observed, but a conical protrusion from the inferior part of this tube indicates the first rudiment of the liver.

At the 90th hour (fig. 1) the anterior of the two

FIG. 1.*

canals is longer and narrower than the posterior; it presents two slight dilatations—the first in the situation where the liver and pancreas are developed; the second, and larger, immediately in front of this, indicating the position of the future stomach. It is at the first-mentioned dilatation, at its upper part, and behind the stomach, that the pancreas is developed. This rudimentary gland consists of a flask-shaped mass of dark granular blastema, connected, by a broad peduncle, with the wall of the intestinal tube, from which it is apparently a protrusion, being of a similar structure with it. That part connected with the

* Represents the anterior prolongation of the intestinal canal at the 90th hour, with the liver and pancreas arising as protrusions from that tube. V. Vitelline Duct; I. Intestine; L. Liver; P. Pancreas; S. Stomach.

intestine is narrow and tubular, its distal portion being spherical, and its surface slightly lobulated. There is no evidence of any subdivision of this body into two portions, nor at its distal end can any trace of a spleen be as yet observed. Nearly the whole length of the above-mentioned two canals have connected with them a delicate fold of membrane—the 'intestinal laminæ,' which serves to connect them with the vertebral column beneath. At the 114th hour (fig. 2) the anterior prolongation of the vitelline sac presents a double curvature, the concavity of one being directed towards the under, of the other towards the upper surface of the embryo; it is in this latter

FIG. 2.*

that the rudimentary pancreas may now be clearly seen. This organ now appears as an elongate, darkly granular, tubular mass, situated in that curved portion of the intestinal canal which is the rudiment of the

* The same parts are represented as they are observed at the 114th hour. The first trace of the spleen is here shown as a small oval body, developed in a fold of the intestinal laminæ distinct from the pancreas. Sp. Spleen.

duodenum; its direction is in the transverse axis of the embryo, one extremity being connected to the primitive intestinal tube, into which it may be seen to open by a distinct tubular prolongation, the other being separated from the spleen by a distinct granular blastema.

The spleen makes its first appearance at this period in a fold of the 'intestinal laminæ,' which below is continuous with the edge of the intestine, as far as the constricted portion of the vitellary sac, and above with the lower part of the rudimentary stomach. It is a small oval whitish mass, situated near to the distal end of the pancreas, but perfectly separate from this body.[1] This distinct separation of the spleen and pancreas is more evident at this period than at any other of its first stages of development, for a distinct granular membrane now divides them, whilst also the dark granular tinge of the pancreatic mass, and the lighter colour of the rudimentary spleen, make this distinction more manifest. At a later period, the

[1] I may here mention that Arnold* states that the spleen arises, like the pancreas, from the duodenum, and exists at first as a common mass with that gland. Whilst Bischoff† believes that it arises from a mass of blastema, at first common both to this organ and the pancreas, that part forming the pancreas proceeding from the duodenum, and that forming the spleen from the great curvature of the stomach. I need hardly say that these descriptions of its origin do not coincide with my own investigations.

* F. Arnold. *Salz. Med. Zeitung.* 1831. T. iv., p. 301.

† J. L. Bischoff. *Entwick der Saugthiere und des Menschen.* Leipzig. 1842. P. 285.

increased size of both organs causes them to approximate more closely, although not more intimately, to one another, and it is this latter circumstance that has probably given rise to the great difference of opinion regarding the development of these parts. The organ, which has now a greyish tinge, lies parallel with the body, and tapers at both ends, the lower one being connected with the fold of blastema attached below to the intestine and vitellary membrane, the upper one continuous with the upper part of the same fold which passes to the surface of the rudimentary stomach.

On the fifth day (fig. 3) the pancreas and spleen

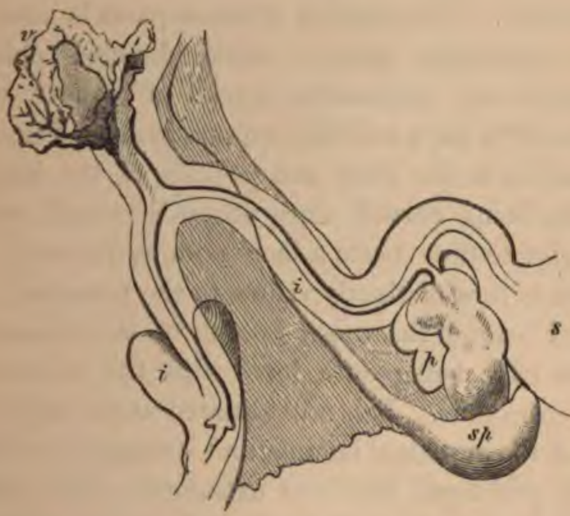
Fig. 3.*

may still be observed as two separate masses, the former of which forms a distinct opaque transverse

* Represents the intestinal canal, pancreas, and spleen from an embryo chick between the 5th and 6th days. The spleen is now observed to have approximated close to the end of the pancreas.

tract of white matter, which stretches upwards and backwards from the rudimentary duodenal loop, the spleen existing as a round reddish mass occupying its opposite extremity. It consists of a dark mass of blastema, distinct from all the surrounding parts; when seen with the naked eye it is of an opaque white, or slightly reddish colour; its shape is reniform,

FIG. 4.*



and it is situated close to the end of the pancreas, below and beneath the rudimentary stomach. The organ consists of part of a tract of blastema, which, at the upper and lower extremities of the spleen, are

* Represents the same parts from an embryo chick between the 6th and 7th days. The pancreas, with its duct, is observed occupying the fold of the duodenum; the spleen being placed at its distal extremity.

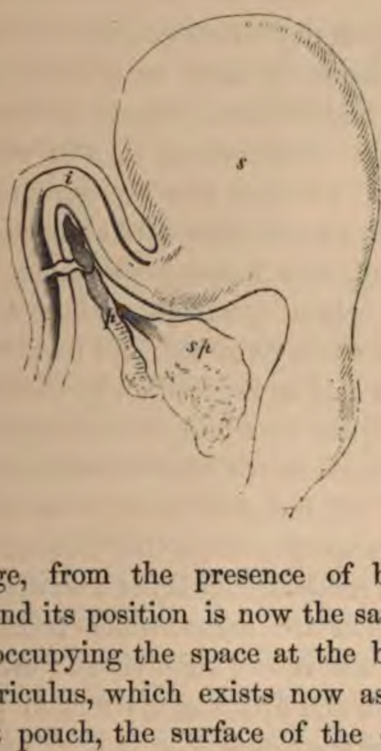
continued from it in one direction towards the lower end of the stomach; in the other backwards, towards the intestine. It occupies the free margin of the fold of the 'intestinal laminæ,' which presents a direction similar to what was observed on the fourth day of incubation.

On the sixth day (fig. 4) the duodenal loop has become completely developed, and in it the pancreas is plainly visible, the spleen occupying its distal extremity. The position of these parts is now, however, somewhat altered, being directed obliquely upwards and backwards, instead of transversely, as on the fifth day; and this appears to depend upon the alteration in the form and position of the intestine, which, being curved more upwards, would necessarily give to these parts a more oblique direction. The spleen is now distinctly visible to the naked eye; it is placed behind the upper border of the stomach, its upper edge being on a level with the rudimentary proventriculus. It is still situated at the edge of the fold of the intestinal laminæ, and its shape is reniform, being prolonged into two extremities, the lower of which is the more distinct, and can be traced for some little distance along the margin and in the substance of this fold, being ultimately lost in it; the other extremity is more rounded, and is connected, through the interposition of the same fold, with the stomach itself. At the point where the spleen is apposed to the pancreas an apparent continuity of substance exists between them, but this is not really so, for the two organs could be observed to be separate,

from the great difference in their texture, the substance of the pancreas being darkly granular, whilst that of the spleen is of a lighter colour.

On the seventh day (fig. 5) the spleen is of a patchy

FIG. 5.*



reddish tinge, from the presence of blood in its substance, and its position is now the same as in the adult bird, occupying the space at the back part of the proventriculus, which exists now as a separate and distinct pouch, the surface of the organ being slightly lobulated, especially towards its two extremities. Its shape is pyriform, the rounded end being

* In this figure are represented the stomach, duodenum, pancreas, and spleen, from an embryo chick between the 7th and 8th days.

directed backwards and upwards, and the narrow end forwards, into the interval between the commencement of the duodenum and pancreas. These two extremities are still connected by folds of membrane with the stomach and mesentery. They proceed from the back part of the organ, and apparently surround it.

On the eighth day the organ has increased in size, being now about as large as a small millet seed, forming a round reddish projecting mass from the surface of the membranous fold in which it was developed, and which is now becoming more delicate and indistinct, as if in process of absorption, although its attachment still remains the same. From this period the spleen gradually enlarges, its colour becomes of a more vivid red, and its form somewhat circular; it is held in its position by the vessels which proceed to it, and by a fold of membrane that passes from its lower end to the inferior border of the stomach, the remaining portion of the membrane in which it was developed having become completely absorbed. With the exception of a continued increase in the growth of the organ, which takes place more rapidly after the vessels supplying it are formed, its form, position, and attachments remain precisely the same as in the adult bird.

From the preceding observations it is seen that the spleen arises in a fold of the 'intestinal laminæ,' as a small whitish mass of blastema, distinct both from the stomach and pancreas, this fold serving to retain it and the pancreas in connexion with the intestine.

This separation of the spleen from the pancreas is more distinct at an early period of its evolution, than later, as the continued growth of both organs causes them to approximate more closely, though not more intimately, to one another. With the increase of growth of the organ and of the surrounding parts, it gradually attains the position that it occupies in the full-grown bird, in more immediate proximity with the stomach; and as soon as its vessels are formed, the membrane in which it was developed becomes almost completely absorbed.

DEVELOPMENT OF THE TISSUES OF THE SPLEEN.

Development of the External Capsule.

THIS makes its first appearance about the ninth day, as an exceedingly thin and delicate finely-granular membrane, in which are imbedded a few nucleated fibres; these fibres soon become more numerous, and the capsule at the same time becomes thicker; and when the development of the organ attains its completion, the entire membrane consists of a dense mesh of minute nucleated fibrillæ.

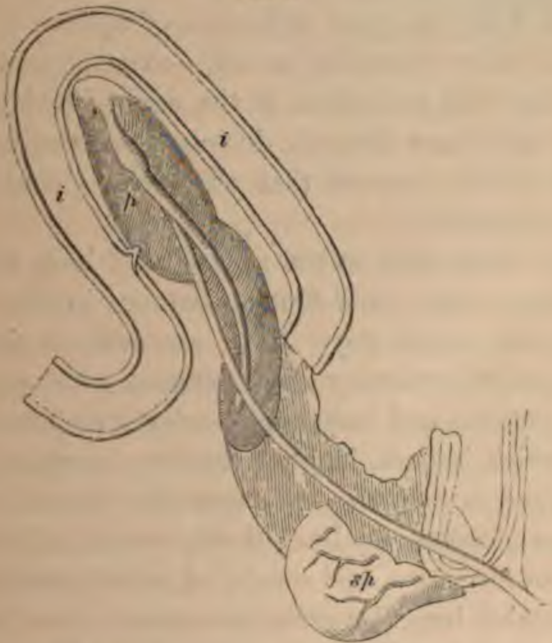
The *trabecular tissue* makes its first appearance in the spleen about the same period with the investing capsule, in the form of a few, and subsequently more numerous, spindle-shaped nuclear fibres, either separate, or collected together into delicate bundles, which intersect the organ, at first sparingly, but afterwards in greater quantity.

ON THE DEVELOPMENT OF THE BLOOD-VESSELS AND THE BLOOD.

The blood-vessels which supply the spleen, the individual vessels of this organ, and the blood, have a completely separate, though concurrent, development. They are all observed about the eighth day. The *splenic artery*, which is developed previous to the vein, may be at this time observed as a delicate white tract of blastema, running from the aorta to the spleen; on arriving at the inner side of this organ, a prolongation of the same colour may be observed, passing to the upper end of the stomach, and one or two to the front of the same organ, it then runs along the inner margin of the spleen, and is ultimately lost in the substance of the pancreas, and in the duodenal fold. No similar tract could, however, be found, after repeated examination, to pass into the substance of the spleen, although at the same period capillaries containing perfectly-formed blood discs, but as yet having no proper coats, and apparently merely formed by the walls of cells agglomerated together, were seen to be arranged in a branching manner, throughout the substance of the organ (fig. 6). On the ninth day this vessel presents a reddish tinge, and its distribution is the same as in the adult bird. Two small branches are now observed to be given off to the substance of the spleen from the vessel previously described, as it runs along the inner side of the organ. When the development of the arteries supplying the organ is completed,

it *increases considerably* in size, and becomes of a dark reddish colour.

FIG. 6.*



The *splenic vein* makes its first appearance about the thirteenth day, in the form of a reddish white tract of blastema, which runs forward, and joins with the left side of the already-formed mesenteric vein. On the fourteenth day it consists of three small branches, larger than the arteries, which, uniting together, empty themselves into the mesenteric vein.

* The duodenum is here represented with the pancreas, and its duct contained in it. The spleen is seen near to its distal end with blood-vessels ramifying in its substance ; no branches being derived from the vessel which runs along its inner side.—From a chick at the 8th day.

The development of the blood globules in the spleen, as well as the various changes they undergo in the substance of this organ, are points of the very highest import, from the great difference of opinion that at present exists regarding its use,—some physiologists believing that the spleen is the organ in which the blood discs are formed, during extra-uterine life, whilst others suppose that the blood globules are destroyed there.

The blood discs in the spleen, as I have already mentioned, make their first appearance in this organ about the eighth day. They are oval or circular, vary in size, consisting of an external envelope, pale, homogeneous, and indistinct, having a nucleus on its wall which is dark, highly refractive, irregularly circular, and in some cases of a granular texture. Some of these globules may be distinctly seen in an incipient stage of formation, and consist of a dark, and at first a somewhat irregular granular nucleus, around which a delicate cell wall may be observed. Although this observation has been confirmed in many cases, I do not presume the spleen to be *the sole organ* in which the *development* of the blood globules takes place, during intra-uterine life; nor have I observed that the development of the blood discs *continues* to take place in it *after* its connexion with the general *vascular system* is effected.

After the most repeated and careful examination I have failed in detecting anything that would lead me to suppose that this organ does, during *its embryonic life*, perform the function Kölliker and others have

assigned to it during its *adult life*, namely, that of destroying the blood globules.

ON THE DEVELOPMENT OF THE PULP.

The pulp tissue being the most important constituent of the spleen, and that in which the chief part of its function resides, its development is a point of much interest, in determining the minute anatomy and physiology of the organ, and the *differences* observed *in its structure* at *certain periods* of development are so striking, as to lead one to the conclusion of their bearing some intimate relation with its use. Now, these differences are observed—1st, during the first periods of its evolution; 2ndly, *after* the development *of the arteries* which supply it with nutrition; and 3rdly, during the development of the veins which return the blood from the organ.

The entire substance of the spleen at an early period is almost entirely composed of nuclei and granular matter. As the evolution of the organ proceeds, part of these elements become developed into trabeculæ, part into blood-vessels and blood, whilst the greater portion remain to form the *essential element* of the organ, the *pulp tissue*. On the fifth day this substance is composed of *nuclei*, varying in form and size. The great majority are irregularly circular, their sides being flattened at some points, so as to give them an angular form; some however are perfectly circular; they are pale, their outer margins dark and well defined, whilst in their interior may be observed

one, two, or more dark granules. These form a very considerable portion of the substance of the pulp, not only at this, but also at every other period of its development. A *few* nucleated vesicles may also be observed, their outer margin exceedingly delicate, and on their wall may be seen a small irregular dark-edged nucleus; sometimes the nucleus is more circular, and contains a nucleolus, whilst the interior of the vesicle contains a few delicate pale granules. With the exception of a few small dark highly-refractive oil granules, and a fine pale granular plasma, in which the above elements lie, they constitute the entire mass of the pulp tissue at this period. The *next change* that is observed, takes place concurrent with the formation of the arteries that supply the organ, and which is soon followed by an increase of its size. Now, besides the elements *already described* as forming its structure, there may be observed nuclei having a quantity of *fine dark granules* surrounding them in a circular form. There are also observed *many* nucleated vesicles, rather larger than the blood corpuscles, the nuclei in which are circular, whilst the cavity of the vesicle contains also a few small pale granules. Some small masses of reddish brown granules may also be observed; they exist, however, very sparingly. From the time when the formation of the arteries supplying the organ is completed, up to that when the splenic vein is formed, these latter elements not only constitute a portion of the pulp, but are in fact its *chief* components; and when the formation of the splenic vein is *nearly completed*, a considerable change

is observed to have occurred in the nucleated vesicles, the majority of which contain a nucleus with irregular margins. Their form is chiefly circular, their outer wall in some cases very distinct, in others less so, from the cell being distended with dark granules; there is generally only a single nucleus, which has a dark outer margin, and contains either a nucleolus, or two or three granules. In some, the nucleus is of an irregular form and more indistinct; the cavity of the cell, in these cases, containing a few granules. As the nuclei become more irregular and granular these granules increase, until at last the nucleus appears to be entirely broken up, when the cells become crowded with small granules. Such is the structure the pulp tissue of the spleen presents, from the period when the splenic vein is formed, up to the time when incubation is completed.

DEVELOPMENT OF THE MALPIGHIAN VESICLES.

The vesicles of the spleen, which form one of the most important elements of this organ in its mature state, are *not developed* until the period of incubation is near *to its completion*. Between the 20th and the 21st days, there may be observed at the angles of division of the smaller blood-vessels, as well as upon the walls of the vessels themselves, rather large masses of nuclei and fine granules arranged together in a circular form; these masses, although not enclosed by any investing membrane, are intimately connected with the walls of the vessels, as they cannot be

removed by delicate manipulation, and only when a greater amount of force is used. A few days after incubation is completed, these vesicles become partly surrounded by a faintly delicate homogeneous membrane, and in about a week they are distinctly formed and present the same structure as in the adult bird; they are circular or oval, varying considerably in size, and consist of an outer investing membrane, pale, homogeneous, or faintly granular in texture, containing in their interior a mass of nuclei and numerous small dark granules.

From the preceding observations, several very important conclusions may be drawn, which may assist in elucidating the physiology of the spleen. These are—first, the *small size* of the spleen in the *fœtus*, as compared with its proportionate *increase after* birth, a fact which would tend to show that it is not an organ the function of which is *mainly* exercised during *intra*-uterine life. Second, the *entire absence* of any evidence, either of the *formation* of the blood-discs in the spleen (after its connexion with the general vascular system is effected), or of their disintegration, shows I think, that it is neither a blood-forming, nor a blood-destroying gland, at least during *fœtal* life. Far more important conclusions may be drawn from the examination of the pulp parenchyma, and the Malpighian bodies. With regard to the former, a distinct process of cell-growth, of ripening, and of cell-destruction has been observed, and these processes have been seen to occur concomitant with the evolution of the vessels of the gland; that of cell-growth

occurring with extreme rapidity as soon as the arteries which supply the organ are formed; then that of ripening, and of cell destruction, taking place to the greatest extent up to, and during the time that the development of the splenic veins takes place; this would seem to show that some secretion took place in the gland, which became collected in it ready to be removed by the veins as soon as their development should occur. Such a process is always to be found going on in man and animals, though ever varying in extent, at all periods, the investigation of which will, however, be noticed in its proper place. The time at which the development of the Malpighian vesicles occurs, viz., not until the period of fœtal life is *just completed*, clearly shows that these structures can have no office whatever during intra-uterine life. Their development appears to occur at a period when, fœtal life being completed, the nutrition of the body is derived from without.

I may here mention that distinct *yellowish green* bile is found in the gall-bladder of the fœtal chick, at a period *considerably antecedent* to the development of the *splenic* vein and its connexion with the portal vein, which disproves the late theory of Kölliker's, viz., 'that the spleen is at least *solely* concerned in producing the *colouring matter of the bile*.'

DEVELOPMENT OF THE SPLEEN IN THE HUMAN SUBJECT.

The earliest period at which I have been able to detect the existence of the spleen in the human embryo, is at the *second month*. (Fig. 7.) I have no doubt, however, that had I been fortunate enough to obtain fœtuses at a much earlier period of their development, its existence would have been detected antecedent to this, judging from the time the same organ appears in the embryo of the chick, and in other animals. The development may probably be dated as commencing as early as the *third or fourth week* of pregnancy. At the second month, the time when first observed, it is distinctly visible to the naked eye, and exists as an exceedingly small, reddish-white mass of blastema, occupying its usual position at the great end of the stomach. Its size is about equal to that of a large millet seed, its form is triangular, and it is connected with the stomach by a thin and delicate gastro-splenic peritoneal fold, being separated from the pancreas by a narrow but well marked interspace. By the third month, (Fig. 8,) it has increased to double its

FIG. 7.*

FIG. 8.†

* The stomach, intestinal canal, pancreas, and spleen of a human embryo at the second month seen from behind.

† The stomach, duodenum, pancreas, and spleen of a human embryo at the third month, seen from behind. The distinct separation of the spleen and pancreas at this period is well seen.

size, and its colour is now of a deep vermilion tinge. Between the fourth and fifth months, its size *rapidly augments*, and the blood-vessels, which are now easily to be traced to the substance of the organ, are observed to be smaller in proportion than in the adult, the splenic artery being *considerably less* than the hepatic. (Fig. 9.)

FIG. 9.*

At the 9th month, however, the splenic artery is larger than the hepatic, as in the adult. (Fig. 10.)

From this period forwards, until the termination of pregnancy, its growth increases slightly in proportion with the growth of the body generally. With regard to the development of the several tissues

* The stomach, duodenum, pancreas, and spleen of a human embryo at the 7th month, seen from behind. The small size of the splenic artery, as compared with the hepatic, is there shown.

Fig. 10.*

of the spleen, they appear to follow precisely the same steps as I have already demonstrated in the embryo of the chick.

DEVELOPMENT OF THE SPLEEN AFTER BIRTH.

The preceding investigations on the development of the spleen, and of its various tissues, have but afforded mere negative results as to any clue in determining the functions of that organ; results, however, which clearly prove that the organ *does not*

* The stomach, part of the intestinal canal, pancreas, and spleen of a human fœtus at the 9th month, seen from behind. The increased size of the splenic artery is also shown.

attain *its maximum* of development during *fœtal life*, and that its conditions of utility need *not* be sought for during *that* period. If it be admitted that the spleen, like other organs, is performing its *function* to the fullest possible extent, when it attains its *largest size*, and when it arrives at its *maximum* of development and growth, then it is proper that we should observe at what period this occurs. Whether at *birth*, or in *early life*, in *adult life*, or in *old age*. For if we can determine from the numerous experiments contained in the following table, that the organ attains its largest size at either of these periods, we shall then obtain a most important clue to our researches; a clue, the discovery of which will limit the investigation more particularly to the *period of its most active growth*, and the comparison of its structure and composition at this period, with that which it presents in its most *inactive state*, will probably lead us, by the differences that we observe, to a correct conclusion as to the function of this organ.

In the following table I have arranged the results of a hundred and sixty experiments on the weight of the organ at different periods of life; from which, I think, a most correct and positive conclusion can be formed, as to the period at which the organ is largest, and, consequently, to that in which its function is being most energetically performed.

Table of Experiments to determine the weight of the Spleen.

FŒTUS: BEFORE BIRTH.

No. of Experiment.	Age.	Sex.	Weight of Spleen.	Average.
No. 1	3 months	. . .	1 grain	
2	4 „	. . .	5 „	
3	5 „	. . .	18 „	
4	6 „	. . .	30 „	
5	9 „	. . .	60 „	
6	9 „	. . .	210 „	

The organ compared with the entire body in the fœtus is at the fifth month, as 1 to 1400; seventh month, as 1 to 700; ninth as 1 to 350.

AFTER BIRTH.

No. of Experiment.	Age.	Sex.	Weight of Spleen.	Average.
No. 7	6 weeks.	. . .	154 grains.	2 ounces.
8	3 years.	Male	14 drams.	
9	3½ „	Male	8 „	
10	5 „	Female	16 „	
11	7 „	Female	14 „	
12	7 „	Female	40 „	
13	10 „	Female	20 „	
14	11 „	Male	22 „	5 ounces.
15	12 „	Female	22 „	
16	13 „	Male	28 „	
17	14 „	Male	48 „	
18	14 „	Female	48 „	
19	15 „	Male	30 „	
20	16 „	Female	46 „	
21	16 „	Female	36 „	
22	17 „	Male	16 „	
23	17 „	Female	37 „	
24	18 „	Female	30 „	
25	18 „	Male	48 „	

No. of Experiment.	Age.	Sex.	Weight of Spleen.	Average.
No. 26	19 years.	Male	76 drams.	5 ounces.
27	19 „	Male	44 „	
28	19 „	Male	52 „	
29	19 „	Female	68 „	
30	20 „	Female	40 „	
31	21 „	Female	68 „	7 ounces.
32	21 „	Female	38 „	
33	21 „	Male	70 „	
34	21 „	Male	24 „	
35	22 „	Male	40 „	
36	22 „	Male	72 „	
37	22 „	Female	96 „	
38	22 „	Female	56 „	
39	23 „	Male	74 „	
40	24 „	Male	38 „	
41	24 „	Male	54 „	
42	25 „	Female	58 „	
43	25 „	Male	56 „	
44	25 „	Female	48 „	
45	26 „	Male	70 „	
46	27 „	Female	46 „	
47	27 „	Male	26 „	
48	27 „	Male	26 „	
49	27 „	Male	104 „	
50	27 „	Female	32 „	
51	27 „	Male	44 „	
52	28 „	Male	58 „	
53	28 „	Male	60 „	
54	28 „	Male	24 „	
55	29 „	Female	56 „	
56	29 „	Female	48 „	
57	30 „	Male	76 „	
58	30 „	Male	90 „	
59	31 „	Male	40 „	6 ounces.
60	32 „	Male	44 „	
61	32 „	Male	72 „	
62	32 „	Male	78 „	
63	32 „	Male	56 „	
64	33 „	Female	32 „	
65	33 „	Male	24 „	
66	33 „	Male	108 „	

No. of Experiment.	Age.	Sex.	Weight of Spleen.	Average.
No. 67	34 years.	Male	96 drams.	6 ounces.
68	34 „	Female	30 „	
69	35 „	Female	54 „	
70	35 „	Female	44 „	
71	35 „	Female	44 „	
72	35 „	Female	40 „	
73	36 „	Male	56 „	
74	36 „	Male	68 „	
75	36 „	Male	80 „	
76	36 „	Male	48 „	
77	37 „	Male	44 „	
78	37 „	Male	24 „	
79	37 „	Male	44 „	
80	37 „	Male	44 „	
81	38 „	Male	44 „	
82	38 „	Female	22 „	
83	38 „	Male	66 „	
84	38 „	Male	88 „	
85	38 „	Male	32 „	
86	38 „	Male	40 „	
87	38 „	Male	56 „	
88	39 „	Female	44 „	
89	40 „	Female	35 „	
90	40 „	Male	38 „	
91	40 „	Male	26 „	
92	40 „	Female	37 „	
93	40 „	Female	38 „	
94	40 „	Male	32 „	
95	40 „	Male	34 „	
96	40 „	Male	44 „	
97	41 „	Male	94 „	5 ounces.
98	41 „	Female	16 „	
99	41 „	Male	68 „	
100	42 „	Male	20 „	
101	42 „	Female	28 „	
102	43 „	Male	26 „	
103	43 „	Male	34 „	
104	43 „	Female	54 „	
105	44 „	Male	40 „	
106	45 „	Male	51 „	
107	45 „	Female	44 „	
108	45 „	Female	48 „	

No. of Experiment.	Age.	Sex.	Weight of Spleen.	Average.
No. 109	46 years.	Female	52 drams.	5 ounces.
110	46 "	Male	36 "	
111	46 "	Male	28 "	
112	48 "	Male	36 "	
113	48 "	Female	22 "	
114	49 "	Male	92 "	
115	49 "	Male	44 "	
116	50 "	Male	75 "	
117	50 "	Male	46 "	
118	50 "	Male	46 "	
119	50 "	Male	27 "	
120	50 "	Male	38 "	
121	50 "	Female	30 "	
122	51 "	Female	41 "	
123	51 "	Male	26 "	
124	51 "	Female	44 "	
125	51 "	Male	64 "	
126	52 "	Male	56 "	
127	52 "	Male	40 "	
128	52 "	Male	28 "	
129	52 "	Female	40 "	
130	53 "	Male	82 "	
131	56 "	Male	60 "	
132	57 "	Female	30 "	
133	58 "	Male	40 "	
134	58 "	Female	28 "	
135	58 "	Male	72 "	
136	58 "	Female	36 "	
137	59 "	Male	56 "	
138	60 "	Female	28 "	
139	60 "	Female	37 "	
140	60 "	Male	19 "	
141	60 "	Male	52 "	
142	60 "	Male	24 "	
143	61 "	Male	40 "	4½ ounces.
144	61 "	Male	52 "	
145	61 "	Male	32 "	
146	63 "	Male	48 "	
147	64 "	Female	12 "	
148	64 "	Male	52 "	
149	64 "	Male	24 "	
150	65 "	Male	42 "	

No. of Experiment.	Age.	Sex.	Weight of Spleen.	Average.
No. 151	65 years.	Male	32 drams.	4½ ounces.
152	65 "	Male	52 "	
153	65 "	Male	36 "	
154	66 "	Female	44 "	
155	67 "	Male	28 "	
156	73 "	Male	56 "	
157	74 "	Male	24 "	
158	76 "	Female	20 "	
159	80 "	Male	22 "	
160	82 "	Male	16 "	

In adult life, the organ as compared with the body, is as 1 to 320; to 340; to 400. In old age, as 1 to 700.

The conclusions at which I arrive from these data are—first, that the spleen attains its greatest size *during* adult life; but, although the organ does attain its largest size during that period, if we consider the weight of the organ *in proportion with the entire body* at the different periods of life, it will be observed that the size of the spleen increases very rapidly in the embryo from about the 6th month, and that *at birth*, its weight in proportion to the entire body, is *almost equal* to what is observed in the adult; being at birth, as 1 to 350, whilst in adult life it varies from 1 to 320, to 340, or 400. In old age, on the contrary, the organ *not only decreases in weight*, but *decreases* considerably *in proportion to the entire body*, bearing a proportion to the body, as 1 to 700, its weight being reduced by one half less than its average during early or adult life. Notwithstanding, however, these changes, the organ remains persistent throughout the latest periods of life; although undoubtedly its

smaller proportional weight is in exact harmony with a decrease in its functional activity.

These facts then, I think, unquestionably prove that the spleen attains its largest size and exerts its peculiar function between the *periods of birth*, and the *later periods of adult life;* or, in other words, during the most active periods of *growth* and *nutrition* of the body.

But although this important conclusion has been derived from the analyses of these experiments, it will be necessary to ascertain in the next place, whether the spleen can be considered as an organ *the activity of which is constant and invariable* throughout the *whole* of that period; or whether it is an organ, the function of which is *occasionally* or *periodically* brought into action during the same time; and if the latter is really the case, then to determine as far as possible the laws which regulate such periodicity of action.

If a *second* and *more careful* analysis of the preceding table be made, it will be observed that although the activity of the spleen is greatest *between the periods* above mentioned, yet the *weight* of the spleen in *different individuals of the same age*, and at *different periods of life*, presents *every* shade of variety; for instance, it is seen that at the age of 22 the spleen in one individual weighs 40 drams, in another of the same age, 72, or nearly twice the weight. Now can this *altogether be ascribed* to individual peculiarity?—I think not; for although there is no doubt that each organ

may present in each individual of the same age differences in their weight, which may be ascribed to an extreme vigor of constitution in one case, or to a feebleness in another, still no organ, as far as I am aware, in a state of health presents the same extremes of size that the spleen does—extremes of size that are to be observed at every period between birth and the termination of adult life, or in other words, during the *growth* and *nutrition* of the body. Let me, in the next place, examine the laws that govern these differences. Physiologists, since the period when Stukely advocated his views of the diverticular function of the spleen—views more minutely and philosophically explained by Dobson—have stated these differences in the size of the spleen to occur periodically, and to be in intimate connexion with the different periods of the digestive process. Now it is obvious that these differences could not be observed in the human subject by direct experiment; I consequently had recourse to a second series of experiments on the spleens of rabbits, in order to investigate this interesting point. Having previously determined the *average* weight of the spleen in the rabbit to be about 8 grains, I fed them and examined the spleen as to its weight at varying periods of the digestive process, the results are set down in the following table.

Table of Experiments to determine the Weight of the Spleen in the Rabbit during the Digestive Process.

No. of Experiments.	No. of hours after feeding.	Average weight of Spleen.
4	2	6 grains.
4	5	8
5	8	8½
4	10	10
5	12	11½
4	24	7
4	48	7

Variation in the Weight of the Spleen according to the State of Nutrition.—The spleens of highly fed rabbits weighed, 11 hours after ingestion of food, 19 grains (average of 5 experiments); the spleens of rabbits starved weighed 3 grains (average of 4 experiments.)

From these experiments, it may, I think, be deduced that the weight of the spleen *increases considerably* during the time when the digestive process is near to its completion, at the time when the new material is about to be, or has become, converted into blood; and that it *decreases considerably* in weight at varying periods *after* that process has been finally completed.

Now if it has been admitted that the size of an organ affords a just criterion of its activity of function, two very important facts to assist in the present investigation have been proved, viz., 1st, that the function of the organ (whatever that may be) is *being carried on* from the period of birth, until the completion of adult life; and 2ndly, that this function is periodically manifested and is brought into action at a time when new material is being added to the system.

Moreover, it would appear that the weight of the organ, and consequently its activity of function, vary considerably according to the state of the *general nutrition.* If, for instance, the average weight of the organ in the rabbit is *eight grains*, it has been found that where *nutrition* has been carried by feeding *to excess*, and to *such excess*, that much more is supplied than is demanded by the waste and nourishment of the body, *the increase* in the weight of the spleen is considerable, being on an average *nineteen grains*, or more than *twice its normal size.* On the contrary, where nutrition has been suspended (by starvation) to excess, and to such excess that none has been supplied, even for the nourishment or waste of the body, the diminution in the weight of the organ is considerable, being on an average *three grains*, or less than half its normal size. Now these weights represent the two extremes of a scale, the intermediate portions of which exhibit every variety to which the nutrition of the body and the size of the spleen may be subjected.

Lastly, the *weight of the spleen*, and consequently its activity of function, do not present *the same* differences *during* the varied stages of *the digestive process*, where these *extremes* of weight in the organ are dependent on the general nutrition being carried to excess or to deficiency. For in *starved animals* the weight of the spleen *does not increase* during the completion of the digestive process; whilst in *highly fed* animals the weight of the organ *not only increases*, but increases *considerably in proportion* to those where

normal nutrition is being carried on. Such appear to be some (probably) of the few complex laws which are in action, and which determine the activity of the organ under certain circumstances; laws, the broader outlines of which are seen, but the minuter variations, acting under peculiar and special circumstances, whilst they elicit our admiration, are too complex for the most careful investigation, even with all the refinements which at the present day science presents.

The results of the preceding investigations on the development of the organ, appear to be these:—

1st. That the size, and consequently the activity of the spleen, are called into action from the period of birth to the termination of adult life.

2nd. That its size, and consequently its function, are periodically manifested and increased during and after the completion of the digestive process.

3rd. Its size varies considerably according to the state of nutrition of the body, being *increased considerably* in highly fed, and diminished in starved animals.

4th. Independent of these extremes of size, consequent upon the nutrition of the body, it increases considerably after the completion of the digestive process, in the highly fed animals; whilst in the opposite case, no difference in its size is observed.

PART III.

ON THE STRUCTURE OF THE SPLEEN.

THE structure of the spleen in its mature state, is composed of numerous parts, each of which requires a separate consideration. These are 1st. The outer investing tunic, and the trabecular framework of the organ. 2nd. The blood-vessels and the blood. 3rd. The pulp. 4th. The Malpighian corpuscles. 5th. The lymphatic vessels and the lymph; and lastly, the nerves of the organ.

With regard to the general anatomy of the spleen, its variations in form, its varied position under certain circumstances, its relation with other organs, its peculiar colour and consistence, all these are points which are so abundantly treated of in most works upon anatomy, that I have thought it unnecessary even to allude to them, more especially as I am quite unable to add any fresh information to this part of my subject. My investigations have more especially led me to consider the minute structure and chemical composition of the most essential elements of this gland, the results of which will, I hope, when taken in connexion with the composition of the entering and emerging blood, and of the lymph, serve to explain the function and uses of this organ.

STRUCTURE OF THE EXTERNAL TUNIC.

The outer covering of the spleen consists of two layers, which in man are intimately blended together. The external of these is the serous covering; the internal one, the fibrous elastic coat. The *serous covering* of the spleen is merely a reflection of the peritoneum which covers its external surface, giving it its smooth and shining appearance. In man it is exceedingly thin, and intimately adherent to the fibrous coat beneath. It covers the whole external surface of the organ, excepting at the point where the vessels enter at the hilus; it is here reflected from it to the stomach, to form the gastro-splenic ligament; it is also reflected from the upper end of the organ on to the diaphragm, and is continuous with the peritoneum in this situation, where it covers the under surface of this muscle. The structure of this membrane is similar to that of the peritoneum in other situations, consisting of a layer of fibro-cellular tissue, composed of white fibrous tissue and curling elastic fibres, on the surface of which may always be observed in the fresh state, a delicate layer of tesselated epithelium. In the fine cellular tissue which connects this with the fibrous coat beneath, may be found, and more especially in animals, a delicate plexus of capillary vessels. In many of the mammalia the structure of this membrane is precisely similar to what has been observed in man, whilst in some others, as the ox, sheep, and pig, the membrane is thicker, more loosely

connected with the parts beneath, so that it may be easily separated, as a continuous membrane, from the fibrous coat.

STRUCTURE OF THE FIBROUS COAT OF THE SPLEEN IN THE HUMAN SUBJECT.

The fibrous elastic coat is a thin, whitish, moderately transparent membrane, which completely invests the exterior of the organ, and at the hilus is reflected inwards throughout its entire substance, in the form of vaginæ, or sheaths, on the vessels and nerves. The outer surface of this membrane is perfectly smooth, and presents a shining appearance, from the thin and delicate layer of tesselated epithelium which covers its surface, for this membrane (the serous) cannot be dissected as a separate layer from the fibrous tunic, as in many of the mammalia.

The under surface, when carefully dissected from the splenic substance with which it is in contact, presents here and there a number of small whitish elevated points, indicating the situation where the trabeculæ are attached to the inner surface of this tunic, the intermediate portions being perfctly smooth, and in contact with the parenchyma. If a portion of this membrane be carefully torn up and examined with a magnifying power of 350 diameters, it will be seen to be composed of a close and dense mesh of the fibres of white and yellow elastic tissues, the latter of which very considerably predominates. The white fibrous tissue, and the other variety also, present some

differences in their structure to the same tissues examined from other situations. The white fibres are less distinctly of a fibrous structure, they are exceedingly delicate, and of a peculiar granular appearance, not presenting that distinct fibrillated structure which is so peculiar a characteristic of this tissue in other parts; the fibres are also more closely packed together; the addition of acetic acid swells up this tissue into a homogeneous mass, and brings into view numerous oval or oblong-shaped nuclei, with dark, irregular, and highly refractive outer margins, and containing in their interior, in some cases, a few dark granules, some of a circular shape, and others of an irregular circular form. The yellow elastic tissue, which forms the chief mass of this tunic, is peculiar in consisting entirely of the finer variety of these fibres, the great majority of which are less than the 10,000th part of an inch in diameter; they are disposed in their peculiar curly and wavy form, and by their complex interlacement form a number of delicate areolæ, filled up by the other element. They are very short and narrow, and present the appearance of solid fibres, the margins of which are dark and highly refractive; they are disposed in short curls, entwining intimately one with another. No trace of muscular fibres, or of elongate fibre cells, are found in this tunic in man.

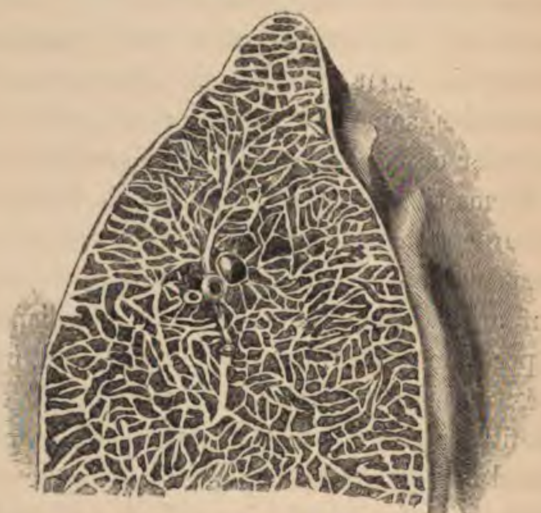
The fibres composing this tunic are arranged in bands, which chiefly run parallel in the long axis of the organ; and at the point where the trabeculæ are attached to it, the fibres from these bands converge

to form them; other bands cross these at various angles, both in a transverse, and in an oblique direction; they are not, however, very numerous.

STRUCTURE OF THE TRABECULAR TISSUE.

The trabecular tissue (fig. 11) consists of numerous fibres, of varying size, of a pearly whiteness, and

FIG. 11.*



of a flattened or cylindrical form, which arise from the inner surface of the investing membrane of the organ. These dividing, or blending together, traverse the soft tissue of the spleen in every direction, forming a dense net-work, which bears a close resemblance

* A portion of the spleen of the sheep, washed to display the trabeculæ (natural size.)

to that of the corpora cavernosa. These fibres do not arise solely from the interior of the investing membrane, many being given off from the sheaths of the vessels, both arteries and veins; and these also blend with those coming from the external tunic. They are chiefly solid, and their size varies very considerably; the largest visible to the naked eye measure between the 100th and the 180th part of an inch in diameter; the smallest, the 500th part; the average size is the 250th to the 300th part of an inch. Their length also varies, some uniting with a neighbouring one almost immediately after its origin, others proceeding for some short distance before their junction takes place. The direction which these fibres take, although variable, is chiefly in the transverse axis of the organ. The fibres, after proceeding a determinate course, unite together, forming, by their junction, areolæ, or interstices, in which are lodged the pulp tissue, the Malpighian corpuscules, and the smaller capillary vessels. At some points, where the fibres become blended, a flattened, knot-like nodulus is formed, not unlike a nerve ganglion; where such is the case, generally four or five fibres assist in its formation; more frequently, however, the fibres unite without such enlargement.

The interstices formed by the union of the trabeculæ are hollow spaces, which communicate freely with each other, and are not lined by any investing membrane, as was supposed by some of the older anatomists. Their size and shape vary very considerably. The larger spaces, which are few in number, measure

about a quarter of an inch in diameter; the smallest, which are more numerous, about the hundredth part of an inch; the average size is about the tenth part. The shape of these spaces also varies very considerably; some are quadrilateral, others hexagonal, some triangular. I shall now consider the minute structure of the trabeculæ.

The larger trabeculæ (fig. 12) are composed of the same elements as the external tunic, of which they are

FIG. 12.*

* A portion of five of the larger trabeculæ at their point of junction, from the human spleen, magnified 300 diameters.

but internal prolongations, consisting of white fibrous tissue and the yellow elastic fibres. The white fibres composing the larger trabeculæ consist of numerous exceedingly delicate, pale fibrillæ, the smallest of which vary in size from the 10,000th to the 15,000th part of an inch in diameter. These fibres are chiefly

FIGS. 13 & 14.*

arranged parallel with one another, and in the long axis of the trabeculæ; a few, however, are occasion-

* The two drawings in this figure illustrate the structure of the trabeculæ from the human spleen, as displayed by the action of water, *a*, and of acetic acid, *b*.

ally observed to cross these, both in a transverse and also in an oblique direction; they present their characteristic wavy appearance, but they are somewhat more granular in texture, and less distinctly fibrillated, than the same tissue from other parts. Interspersed among these may occasionally be observed a few nuclei, of an irregular oval or circular form. The application of acetic acid (figs. 13 & 14) swells up this tissue into a pale faintly granular homogeneous mass, at the same time bringing into view the nuclei of this tissue. They are chiefly of an irregular circular, or of an elongate oval form, their outer margins darkly lined and distinct, the interior containing one or two small dark granules. The yellow elastic fibres (fig. 15) form a very considerable portion of the substance of the larger trabeculæ; they are not easily seen until acetic acid has been added; they consist of fine, delicate, solid, branching fibres, the average size of which is about the 10,000th part of an inch, pre-

Fig. 15.*

* One of the larger trabeculæ from the spleen of the sheep acted upon by acetic acid, which displays a large number of yellow elastic fibres.

senting their peculiarly characteristic wavy and tortuous course; they also run parallel with one another, and chiefly in the long axis of the trabeculæ, apparently forming an intricate blending with the white fibres. Their structure appears to be similar to that found in other parts; they are, however, somewhat smaller in size.

There are also occasionally to be observed a few nucleated fibres; they are short curved fibres, having a roundish nucleus. The fibre itself is granular in texture; the outer margin of the nucleus is well defined, the interior generally containing three or four granules, seldom a nucleolus.

At the point where the trabeculæ blend with one another, the bands of fibrous tissue of which they are severally composed interlace, so that the fibrillæ of one band blend with two or three others, by an interlacing of their filaments at their point of junction. A similar arrangement also prevails at the point where the trabeculæ are attached to the external tunic or to the sheaths of the vessels. (See fig. 12.)

The *smaller trabeculæ* consist of delicate fibrillæ of white fibrous tissue; about the centre of some of these fibres may sometimes be observed elongate, oval-shaped nuclei, with a dark outer margin and somewhat granular interior. Some of these fibres are separate, having a circular nucleus at one extremity, containing two or three granules in their interior; the nuclei are for the most part of an elongate oval form, either pointed or rounded at both extremities, from which proceed either one or several delicate fibrillæ, some-

times joining with the fibrillæ from neighbouring nuclei. The application of acetic acid brings into view numerous delicate elastic fibres, which form an exceedingly close and dense mesh, and which are intimately blended with the white fibres. The diameter of these seldom exceeds the 12,000th part of an inch.

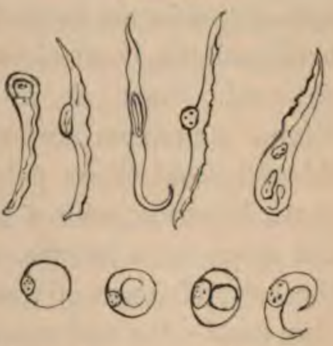
Besides the smaller trabeculæ only just visible to the naked eye, there are others which are microscopic (fig. 16), and which can only be observed by the aid of this instrument. They are connected with the walls of the capillary vessels, just as the larger trabeculæ are connected with the sheaths of the larger vessels, and also form, by their interlacing like the larger ones, small meshes or spaces, in which the parenchyma cells of the pulp are deposited. The structure of these varies, that is to say, they present themselves in four forms. 1st. They may be composed of a structure similar to the larger trabeculæ, consisting of about equal parts of the white and yellow elastic fibres, some of the latter tissue only. 2nd. Some are composed of a small proportion of the fine yellow

FIG. 16.*

* A portion of one of the microscopic trabeculæ from the human spleen, composed of a delicate flattened fibrous membrane, in which are imbedded elongate nuclei, magnified 400 diameters.

elastic fibres, but chiefly of elongate nucleated spindle-shaped fibres, the latter being arranged in a linear direction. The above-mentioned fibres, which I have described as being confined almost entirely to the smaller microscopic trabeculæ, have been regarded as muscular; but they differ in their structure in many respects from the *muscular fibre cell*, to which they bear no resemblance, and their mode of development affords a still greater proof that they cannot be considered as similar structures. They are spindle-shaped, nucleated fibres, which generally are somewhat curved, or curled up; their length varies between the 300th and the 500th of an inch; their breadth is about the 5000th. Their structure is homogeneous, or finely striated longitudinally; their edges, more particularly on one side, being undulated, or serrated. The nucleus, which is generally imbedded near their centre, is either of a circular or oval form, its outer margin is distinct and darkly lined, its interior containing two or three dark granules. More rarely, the nucleus is elongated. In the great majority it projects from the margin of the fibre, but in some cases occupies the centre, or its extremity, or is occasionally connected

FIG. 17.*



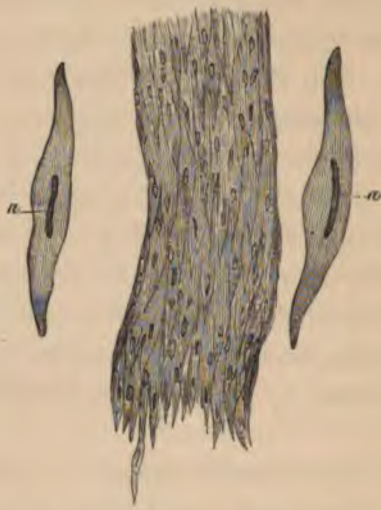
* This figure illustrates the structure and development of the nucleated fibre cells from the human spleen. Mag. 400 diam.

by a narrow peduncle with the fibre itself. The development of these structures is somewhat remarkable, and at once serves to demonstrate the difference between them and the muscular fibre cells. They first appear in the form of a simple spherical-shaped nucleated cell, in which no trace of any fibre is to be observed. Now, as is already known, ordinary fibrous structures are formed by the elongation of this cell, from either pole of the nucleus. In these fibres, however, such a process does *not* occur: the cell at one point becomes apparently absorbed, so that the circumference of the wall of the cell forms the fibre itself,—the cell breaking at one point, whilst the nucleus retains its original position in the cell wall. The fibre, when first formed, retains its peculiar original form, being curled up in such a way that the extreme ends of the fibre are in opposition with one another. By degrees, however, each fibre assumes its elongate form; but even in the majority, a slight tendency to a curved form may be seen on that margin of the fibre from which the nucleus projects. I should regard these fibres merely as a variety of ordinary fibrous tissue. I do not consider that in any respect they can be looked upon as muscular, the difference in their structure, and in the mode of their development, being both against such a supposition. 3rdly. Some, and apparently those derived from the sheaths of the small vessels, are composed *entirely* of elongate nucleated spindle-shaped fibres, the fibres being arranged parallel with one another. The nucleus which occupies the centre of the fibre presenting an external

dark outer line, its structure is homogeneous, containing neither nuclei nor granules. In some cases the fibres from one nucleus join with those from a neighbouring one. 4th. Some of the trabeculæ which are derived from the sheaths of the vessels are composed of indistinct granular membranes, containing scattered circular-shaped nuclei, and having neither elastic nor spindle-shaped fibres entering into their composition. These, however, are not frequently to be observed. The whole of the above-mentioned forms, as I have before said, are microscopic, and intersect the spaces formed by the junction of the larger trabeculæ.

In some of the mammalia, and also in other animals, in addition to the usual constituents of the external capsule and trabeculæ, may be observed other elementary structures, which have been regarded as muscular (Fig. 18). These consist of fibres which exist separately in small bundles, or more frequently are blended with the yellow and white fibres of the trabeculæ. They consist of exceedingly pale, flattened, spindle-shaped fibres, each of which contains a nucleus, which is usually rod-like. They vary in *length*, the average being about the 400th *of an inch*. They are about the 2000th of an inch broad. The nucleus has a length of about the 1200th, and the breadth about the 10,000th. They present a clear and well-defined margin, and their structure appears to be finely granular, or longitudinally striated. The nucleus occupies a varying position, most frequently at the centre of the cell, sometimes at one end. It is elon-

Fig. 18.*



gated, rod-like, its structure being pale, almost as the cell in which it is contained. In some cases the nuclei are of an oval form, or narrow, elongated and undulating, rarely spherical. The relative number of these fibres is very different; in the *larger* trabeculæ in the pig, they are blended with the white and yellow elastic fibres in nearly equal quantity, the fibres being arranged side by side, dovetailed one within another, and running in *the long axis of the trabeculæ*, never transverse. In the small microscopic trabeculæ, they form in some cases the sole, in others the chief constituent, only a few curling elastic fibres being present. In some cases they are arranged together so as to

* The drawings in this figure illustrate the muscular fibre cells from the spleen of the sheep. Magnified 400 diameters—*a a* the same fibres more highly magnified.

form bands of various sizes, which, when acted upon by acetic acid, are seen to consist of a mass of the fibres above mentioned, arranged parallel with one another, and containing their characteristic nuclei, being quite unmixed with either the white or the yellow curling fibre.

In the *external tunic*, they are not to be found in the human subject, rabbit, horse, ox, guinea-pig, hedgehog, and some others; but they are found in the pig, dog, and cat. In the trabeculæ, they are seen in the ox, the dog, the cat, and the ass; in sheep, the rabbit, the horse, the rat, the guinea-pig, and the hedgehog.

Many very important conclusions may be deduced from the structure presented by the external capsule and trabeculæ.

It has been seen that the main part of their structure consists of *yellow elastic* fibres; it is no doubt owing to their presence that the spleen possesses a very considerable amount of elasticity, admirably calculated for the varied and occasionally very considerable changes of volume that it has been shown to present under certain circumstances. This increase of size mainly depends, as I shall elsewhere show, upon the increased amount of blood that the organ under certain conditions contains; and I offer this remark now, in order to explain another highly important office that the elastic fibres possess. I believe that they not only allow the extreme variations dependent on the increased amount of blood, occasioned either by sudden repletion of the vascular system, or

by any mechanical hindrance to the circulation, but they also serve, by the same elastic property, to expel the blood again when the circulation is uninterrupted, or when it has assumed its normal standard of repletion.

ON THE CONTRACTILITY OF THE SPLEEN.

Whether the spleen can be considered as a contractile organ or not, is a point which has been left as much undecided as the function of the organ itself. In the structure of the external capsule and trabeculæ of the spleen in man, no trace has been discovered of the existence of muscular fibre, and the recent experiments made by Kölliker, on the same organ, from the body of an executed criminal, by means of the galvanic current, failed to afford the least evidence of its contraction. In many other animals, on the contrary, the existence of elongated nuclear fibre cells, which are regarded by Kölliker as muscular, are to be found in great abundance in the capsule and trabeculæ of the organ; the following are the results of the experiments I have made on these animals, in order to examine this point. A detailed account of the experiments themselves I have appended below.*

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* ON THE SPLEEN OF THE OX.

Experiment 1.—The wires of a strong galvanic battery were applied in the transverse axis of a bullock's spleen, *three-quarters-of-an hour* after the death of the animal, but no effect was produced: *distinct contractions* were, however, observed on applying the wires to the *voluntary muscles*, and *less marked* on the *large* and *small intestines*.

Experiment 2.—A similar experiment was performed on a bul-

The application of a strong galvanic current, gave, in some cases, and in some animals, faint traces of contraction. I have performed these experiments repeatedly on *sheep*, *oxen*, dogs, and cats. In the two *former*, I never in any instance found the least

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lock's spleen, *ten* minutes after the death of the animal, but with the same negative results,—no diminution of its breadth, or corrugation of its surface, was to be observed. Visible contractions of the voluntary muscles and bladder were produced.

Experiment 3.—In this experiment the poles of the galvanic current were inserted into the *substance* of the spleen, but no wrinkling or corrugation on the surface of the organ was produced.

Experiment 4.—This experiment was again repeated and with a similar result.

ON THE SPLEEN OF THE SHEEP.

Experiment 5.—On applying the wires to the spleen of a sheep *ten minutes* after death, and *previous* to its removal from the body, no effect was produced on it except the movement communicated to it by contraction of the diaphragm. It was then removed from the body, but no contraction or corrugation of its surface could be discerned, either on applying the wires to the surface, or in the interior of the viscus. The contraction of the muscular fibres of the gullet, large and small intestines, and bladder, was well marked.

Experiment 6.—The above experiment was repeated on a spleen removed from the body, but no effects were produced. In the gullet, the large and small intestines, and the bladder, the contractions were well marked.

Experiment 7.—A similar experiment was attended with similar results. The spleen, in this case, was removed from the body *five* minutes after death. The contractions of the bladder were so powerful as to expel the urine from its cavity.

Experiment 8.—A sheep was opened *five* minutes after death; *eight* minutes after, very strong contractions were observed in the œsophagus on the application of the wires: twelve minutes after the spleen was removed, but no visible effects were produced on the surface of this organ. Fourteen minutes after death, *and after*

evidence of contraction in the organ, or any alteration in the appearance of its surface, although the galvanic current was applied for a considerable time, and within a period after death varying from eight to

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the application of the wires to the spleen, contraction of the muscular fibres of the intestine and bladder was very powerful.

Experiment 9.—This experiment was again repeated with a similar result.

Experiment 10.—A sheep was opened *ten minutes* after death, and a portion of the œsophagus being immediately removed, very strong contractions were observed on the application of the wires, fifteen minutes after death the spleen was removed, but not the least effect on this organ was produced. Eighteen minutes after death, very strong contractions were exhibited in the small intestines, sufficiently powerful to expel the contents of the gut.

ON THE SPLEEN OF CATS AND DOGS.

Experiment 11.—A well-fed and healthy cat being placed under the influence of chloroform, was immediately opened, and the spleen exposed. On applying the wires of the galvanic apparatus to several points in succession, on several parts of its surface, a *slight curling up* of the *edges* of the *organ* was *observed*. Afterwards, on applying the wires in the transverse axis of the narrowest part of the organ, a slight alteration on its surface was produced;—it became paler in colour, granular, and appeared somewhat as if impressed with a cloth; it also presented a wrinkled and corrugated appearance.

Experiment 12.—The above experiment being repeated, the same results were observed.

Experiment 13.—A healthy cat being fed eight hours previous to the following experiment, was placed under the influence of chloroform; the body was immediately opened; the spleen was found to be large, and studded with prominent granular points. Repeated application of the galvanic current finally produced a distinct wrinkling and corrugation of its surface, but no *contraction* of the organ was observed.

Experiments 14 and 15.—The same experiments were again repeated on two more cats, and on four dogs, the same results in *each* case being observed, as above mentioned.

fifteen minutes. In each case, however, the *most marked contractions* were observed on the application of the wires to the œsophagus, the large and small intestines, and the bladder.

In the latter animals, (dogs and cats,) I found, on applying the wires of the galvanic apparatus in the transverse axis of the organ, a slight alteration of its surface was produced—it became paler in colour, granular, corrugated and wrinkled, although its diameter was not sensibly lessened; nor could I ever, in any instance, observe a distinct and well-marked contraction to occur. I have never observed, out of twenty experiments that I performed, that the blood was compressed from the organ by the application of the galvanic current, as has been erroneously asserted by some.

The result of these experiments would lead me to conclude that the application of a strong galvanic current to the spleen, in some animals, is followed by an exceedingly slow and faint contraction, and wrinkling of its surface; this is, however, to so very limited an extent, that it is, I think, impossible to conceive that it can in any way regulate, at least to any considerable amount, the extreme variations in size the organ undergoes under certain circumstances.

THE BLOOD VESSELS.

The Splenic Artery.

THE splenic artery, in the adult, is the largest of the three branches of the cœliac axis, and is remarkable for its peculiar tortuous course. The size of its branches distributed to the organ are very considerable, larger perhaps than are distributed to any gland of its proportionate size, excepting the thyroid. Now this fact is highly important, as when an organ receives more blood than is required for its nutrition, it may be fairly assumed, that either the blood itself undergoes some change, or else a secreting process takes place. The artery arises from the left side of the axis, and passes horizontally to the left, accompanying the splenic vein and the splenic plexus of nerves behind the upper border of the pancreas, where it gives off several branches, (pancreatic,) varying in size and number, to supply the middle and left side of the pancreas; one of these, larger than the rest, and generally constant, takes the direction of the pancreatic duct, running from left to right, and is called the 'pancreatica magna.' The trunk of the artery, which is now reduced in size, on arriving near the spleen, divides into several branches. These are—1st, The splenic; either four, five, or six in number, they vary much in length and size, but they generally retain a peculiarly wavy course, and

running between the layers of the gastro-splenic omentum, enter the spleen by the fissure in its concave surface. The remaining branches are the vasa brevia, and the gastro-epiploica sinistra. The former, which vary in number from four to eight, arise either from the trunk of the vessel, or its branches just before they enter the organ, and run between the layers of the gastro-splenic ligament, to the left extremity of the stomach, where they subdivide, so as to supply both surfaces of this organ, ramifying between its coats, and anastomosing with the coronaria ventriculi, and the gastro-epiploica sinistra arteries.

PECULIARITIES IN THE SPLENIC ARTERY, AS REGARDS AGE AND SEX.

The splenic artery in the female is the same as in the male.

In the fœtus at the fifth and also at the sixth month of development, the splenic artery is, proportionally to the hepatic and gastric, considerably *smaller* than in the adult. Of the three branches of the cœliac axis, the hepatic is much the largest, the gastric and the splenic being of equal size; but at the ninth month a similar arrangement of the vessels does not prevail, the splenic being now larger than the hepatic.

SIZE OF THE SPLENIC ARTERY.

The diameter of the splenic artery, compared with the other branches of the cœliac axis, is as follows:

	Hepatic.	Splenic.	Gastric.
Male at 19,	$\frac{1}{8}$th of an inch—	$\frac{1}{7}$th of an inch—	$\frac{1}{12}$th of an inch.

Vein about $\frac{1}{3}$rd of an inch in diameter.

	Hepatic.	Splenic.	Gastric.
Male at 26,	$\frac{1}{6}$th of an inch—	$\frac{1}{5}$th of an inch—	$\frac{1}{12}$th of an inch.

Vein about $\frac{1}{3}$rd of an inch in diameter.

	Hepatic.	Splenic.	Gastric.
Male at 40,	$\frac{1}{5}$th of an inch—	$\frac{1}{6}$th of an inch—	$\frac{1}{12}$ of an inch.

The thickness of the walls of the splenic artery is equal to, or rather greater than that of the hepatic, but considerably less than that of the cœliac axis. They are, moreover, much thinner than the walls of the aorta above the origin of the renal arteries; an observation at variance with that of Wintringham, who states that the splenic artery is thicker than the aorta above the origin of the renal arteries.[1]

SHEATHS OF THE ARTERIES.—(*Vaginæ Vasorum.*)

Immediately on the entry of the arteries into the substance of the organ, they receive sheaths (vaginæ) in a similar manner with the hepatic vessels. These are derived from an involution of the external fibrous tunic, and they form an investment which completely encloses the arteries. The same sheaths also invest the nerves and veins. They are separated from the proper coats of the vessels by a rather loose areolar tissue, so that they may be torn from one another

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[1] This erroneous observation of Wintringham, I find copied into several articles on the spleen, written by some of the most accomplished anatomists. (See *Article on Spleen* by KÖLLIKER, *Cyclopædia of Anatomy and Physiology*. Part xxxvi., p. 788.)

with considerable facility. On the main trunks of the arteries the sheaths are as thick as the capsule itself; and much thicker than the vessels which they enclose; and although they gradually become thinner, as the vessels subdivide, they continue stronger, thicker, and more opaque than the vessels themselves; and this arrangement exists not only in the primary, but also in the secondary, tertiary, and quaternary subdivisions, as may be shown by careful dissection. At the point where the arteries and veins run side by side they are enclosed in a sheath common to both vessels. This disposition exists usually in the *trunks* and *primary*, rarely in the smaller branches; and at the point where these vessels separate from one another, in order to proceed to their special destination, they each take a complete sheath, by which they are separately surrounded. On the smaller arteries the sheaths still completely surround the vessels, but now a distinct change is to be observed in their structure, for they do not appear to be of the same thickness all round, but are more dense and opaque on that side of the vessel from which the trabeculæ are derived, presenting the appearance of a whitish line running along each side of the vessel, the intermediate portions of the sheath being sufficiently transparent to allow of the injected matter being seen through it; the sheaths gradually diminishing in thickness appear to terminate either in minute trabeculæ, which are given off from the sheath of the vessel just before it subdivides into its minute capillary branches, or as a fine and delicate fibrous membrane which is continued on to the outer wall of the

larger capillary vessels, and into the finer trabeculæ of the pulp. The smaller arteries are held together in their sheaths by a little loose areolar tissue, which however exists in much smaller quantity than that interposed between the trunks, the primary branches and their sheaths. From them are derived numerous trabeculæ of varying size, which, joining with similar bands derived from neighbouring sheaths, or from the investing capsule, form spaces or meshes in which the splenic pulp is lodged; these trabeculæ are derived indiscriminately from all the subdivisions, but they are less numerous, and finer than those derived from the external capsule. The sheaths as well as the vessels which they contain are supplied with blood by means of small branches given off from the vessels themselves; these run and subdivide into smaller twigs in the loose areolar tissue, between the sheaths and the vessels, supplying both these structures.

SHEATHS OF THE VEINS.

The veins of the spleen, like the arteries, are enclosed in sheaths, which form complete coats around them, but present many differences. 1st, The larger venous trunks are surrounded by sheaths, prolongations from the investing capsule, which are common to these vessels and the arterial *trunks;* these are of the same thickness as the capsule itself, and are connected with the vein by areolar tissue, *denser*, however, than that connecting the larger arterial trunks with their sheaths, so that they are separated *less* easily from

one another; 2ndly, The investing sheaths are *much* thicker than the veins themselves, and this disposition exists not only in the larger subdivisions, but also in the smaller branches. In the primary branches of the veins the sheaths slightly diminish in thickness, being thinner than the sheaths surrounding the primary subdivisions of the arteries, and the walls of the veins are so intimately adherent to them, that it is only with considerable difficulty that they can be separated from one another, and in the secondary subdivisions it is impossible to detach them. These sheaths give off from their outer surface numerous trabeculæ, but they appear to be less numerous than those derived from the sheaths of the arteries. The sheaths of the *smaller* veins appear to have an arrangement precisely similar to those of the small arteries; they are delicate, and the sides from which the trabeculæ arise are thicker than the intervening portions, which are more transparent. Consequently they present along their sides an elongated whitish line, to which the trabeculæ are attached; they terminate by dividing into minute trabeculæ, which join with those from the sheaths of the neighbouring vessels, to form meshes in which the pulp and the Malpighian corpuscules are lodged.

The preceding description is confined to the anatomy of the sheaths of the vessels in man; and in most of the mammalia the same arrangement exists. In others, however, as in the pachydermata and ruminantia, some differences occur, which require mention. In these animals, the sheaths of the *arteries and their*

accompanying nerves appear to have an arrangement similar to what is seen in man; they invest the arterial trunks, are somewhat thicker than the coats of those vessels, and are connected to them through the intervention of loose areolar tissue. But with regard to the veins, many differences exist. These vessels, as well as the artery and nerves, immediately on their entrance into the organ *are* surrounded by a complete sheath, *as in man;* but from this point a different arrangement exists. In the first place, this sheath cannot be traced as forming a complete covering for the veins beyond a very short distance, only as far as the origin of the primary branches. Secondly, in the deeper parts of the organ, where the veins still lie by the side of the arteries and nerves, the sheath is only observed on that side so connected; whilst on the remaining portion no sheath exists, or it is so delicate as not to be demonstrable. Thirdly, those subdivisions of the veins that are *not* accompanied by arteries have no sheath, their only coat being formed by the internal lining membrane of the vein.

MINUTE STRUCTURE OF THE SHEATHS.

The minute structure of the sheaths is precisely similar to that of the trabeculæ and fibrous capsule, being, in fact, nothing more than internal prolongations of the latter. The larger sheaths, enclosing the larger branches of the artery and vein together, are tough and strong, and of considerable resistance. They are composed of the same elements as the

trabeculæ—viz., 1st, of *white fibrous tissue;* this is precisely similar to that forming the trabeculæ, being composed of a quantity of exceedingly minute fibrillæ, of a granular texture or of a peculiar wavy outline, the fibres being disposed in the long axis of the sheath. Some of these fibres are nucleated, the nucleus, which occupies the centre of the fibre, being of a circular form, presenting a dark external edge and a finely granular matter in its interior. The application of acetic acid brings into view a considerable number of minute, dark-edged, elongate, oval-shaped nuclei, and a mesh of yellow elastic fibres. These are minute and in considerable quantity, being disposed in a tortuous and curling manner, and intimately blended with the white fibrous element. No unstriped muscular fibres are present.

The sheaths of the smaller arteries and veins are composed of a similar structure to the above-mentioned, and do not differ in any respect from one another, being composed of—

1st. White fibrous tissue.

2nd. Nucleated fibres in small number.

3rd. Curly elastic fibres, of the finer variety.

4th. Free oval-shaped, dark-edged nuclei (by the action of acetic acid).

ON THE MINUTE DISTRIBUTION OF THE SPLENIC ARTERY.

FIG. 19.*

After the main branches of the artery have entered the spleen they are each contained in a sheath which encloses one of the large branches of a vein, and which is common to both, and to nerves and lymphatics, the two vessels lying in apposition with one another, the vein being situated most anteriorly. The trunk of the vessel then runs in the tranverse axis of the organ, from the internal to the external part, diminishing in size during its transit, and taking either a straight or more or less curved course, and giving off, in its passage, anterior and posterior branches; the former, which are the largest,

* A transverse section of the human spleen, showing the mode of distribution of the arteries, and the manner in which their sheaths are formed.

supplying the anterior, and the latter the posterior part of the organ (fig. 19). The primary branches of these vessels are also, in some cases, accompanied by a vein which is enclosed in the same sheath with them, but the smaller subdivisions are unaccompanied by them in most cases. Each of these primary branches which traverse the anterior and posterior subdivisions of the spleen, gives off from its sides, along its entire course, numerous small vessels, and near to the point of its termination breaks up in two, three, or four branches of nearly equal size. Small apertures are found in the walls of the artery at the point from which the branches are derived, but these are far less numerous than is found on the wall of the veins. One of the most remarkable arrangements of the arterial distribution of the spleen is the peculiarity of *each* of the main trunks of the splenic artery, supplying simply that region of the organ in which that branch ramifies, no anastomoses existing between it and the majority of the other branches.[1] I found on injecting one of the main trunks of the artery in the centre of the spleen, that the injected material returned by one or two small vessels in its immediate neighbourhood, but in no instance was any returned by the trunks supplying either end of the organ, although the injection was continued for a very con-

[1] This fact was first ascertained by Assolant, who found on tying a branch of the splenic artery in a dog, that after death, the portion of the spleen to which that branch was distributed, was mortified; the remaining portion being healthy. Heusinger, also, who modified the experiment, found a similar result.

siderable period, and until the whole of the parenchyma supplied by that vessel was completely filled.

I have also observed that the injected material returns *solely* by the corresponding venous branch, or by those in its immediate neighbourhood, never by the veins corresponding to either extremity of the organ. These experiments I think fully confirm the observations of Assolant and Heusinger as regards the isolated distribution of each of the main trunks of the splenic artery in the parenchyma, and distinctly prove that the larger vessels, at least, in the interior of the organ have no anastomoses.

When the smaller ramifications of the arteries become reduced to a size varying from the 150th to the 250th of an inch, they become connected, by means of their sheaths, with the walls of the Malpighian bodies; the arteries, on arriving at the point of connection of these bodies, subdivide generally into two or more branches, and it is usually at their point of bifurcation that the capsule is situated; they then proceed generally without any further subdivision on the exterior surface or in the substance of the capsule itself, and, in some few cases, give off an occasional lateral branch, which ramifies either on the Malpighian capsule or in the substance of the pulp. These branches, on their arrival at the point where they proceed from the surface of the capsule into the surrounding pulp, immediately subdivide into smaller and more minute branches, forming a beautiful tuft or pencil of capillaries, the individual branches of

which are of considerable length, but of very minute size, and exist as beautiful clusters of vessels of a brush-like or tuft-like appearance, (fig. 20,) which

Fig. 20.*

radiate into the substance of the pulp, where in part they unite to form a distinct and minute capillary net.

The capillary network of the interior of the spleen, which many anatomists[1] have denied, consists of a plexus of minute vessels, the diameter of which varies

* One of the small arteries from the human spleen, shewing the tufts or pencilli of vessels arising from it, and their termination in fine long capillaries.

[1] Engel denies the existence of capillaries in the spleen. (*Zeitschrift der Gesellchaft der Aertze in Wien.* 1847.)

from the 3000th to the 12000th of an inch in diameter; these exist in the substance of the pulp and in that part of it which is in contact with the Malpighian sacculi, where they form a distinct vascular plexus around them. Although the vessels themselves are of extreme minuteness, the meshes between them are of rather large size as compared with the capillary net of other glands, being many times larger than the diameter of the vessels themselves. Their walls lie in immediate contact with the pulp tissue, by which means this substance is constantly exposed to the influence of the fluid ingredients of the blood. After the most repeated and careful examination, by means of injection and microscopic examination I have arrived at the conclusion that the capillaries terminate by becoming continuous with the smaller venous

FIG. 21.*

* These figures illustrate the various ways in which the capillaries communicate with the veins. (From the spleen of the sheep.)

trunks (fig. 21). These suddenly become very large after the junction of the capillaries with them, and their walls are of even greater delicacy than the capillaries themselves.

Some of the capillary vessels, however, cannot be traced to be *directly* continuous with the veins,[1] but gradually becoming reduced in size, their wall becomes more delicate, and is finally lost; the injected material then escapes into interspaces in the pulp parenchyma, the walls of which are formed merely by the elements of this substance; they appear finally to communicate with the veins, some of which commence as intercellular spaces, by which they communicate with each other.

On the capsule of the organ the capillaries are arranged in a linear manner in its long axis, and anastomose with each other by means of small transverse branches, at varied intervals (fig. 22.) They consist of a dense plexus, which is contained in the areolar tissue between the serous and fibrous coats, and also in the substance of the latter coat itself. These terminate in small veins, which join those in the substance of the spleen on the surface of the organ.

In all the *mammalia* the minute distribution of the *arteries* and the arrangement and structure of their sheaths is precisely similar in every respect to what I have described in man. With regard to their structure, I have not found that any differences are observed

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[1] Ecker makes mention of the same fact.

between them and the arteries of other parts. The finest capillaries are composed of a delicate homo-

FIG. 22.*

geneous tissue, on or in the wall of which are imbedded oval or circular-shaped nuclei.

In considering the anatomy of the veins of the spleen, I shall first describe the trunk of the vessel and the larger branches, and then consider the method of *origin* of the smaller veins, *their size*, *their form*, and lastly their *structure* and *situation*.

THE SPLENIC VEIN

Commences by five, six, or eight branches, generally as many as there are arterial branches, which emerge from the substance of the spleen at the hilus at the

* The arrangement of the capillary vessels and veins on the surface of the spleen in the sheep is shown in this figure.

same point where the arteries enter. At their emergence they lie anterior to the branches of the splenic arteries, and somewhat inferior to them. These veins unite, soon after their exit, to form two trunks, an upper and a lower one, the former receiving the vasa brevia from the stomach, and the latter the gastro-epiploica sinistra; these soon unite to form a single vessel, which is now situated behind the splenic artery. It is then directed from left to right, running along the upper border of the pancreas in company with the splenic artery, beneath and behind which it is now situated. During its course it receives from below numerous small branches, from the pancreas, and duodenum, and the inferior mesenteric vein, whilst above it has entering into it the right gastro-epiploic and coronary veins; it then passes across the front of the aorta, and gains the under surface of the liver, where it joins nearly at right angles with the superior mesenteric to form the portal vein. This vein is the largest of all the branches of the vena portæ, and, like them, is destitute of valves, possessing a diameter considerably greater than the splenic artery, the proportion being as five to one or two, not only in the trunk, but also in the branches. Notwithstanding its considerable size, the thickness of its coats is very inconsiderable, being, as compared with the splenic artery, as one to four.

On the entry of a trunk of a vein into the substance of the organ, it is enclosed in a sheath common to it and the larger arterial trunks, and these are con-

nected with each other by a rather dense areolar tissue. The walls of the vein are exceedingly delicate, being considerably thinner than the sheath which encloses them. The *trunks* of the vessels, in their passage through the substance of the organ, take a course very similar to the trunks of the arteries, passing in a more or less transverse direction through the gland, from its inner to its outer surface, and giving off branches from either side in an arborescent manner, diminishing considerably in size during their passage.

FIG. 23.*

The trunk of the vein gives off from each side in an arborescent manner, numerous large branches,

* A transverse section of the human spleen, showing the large size of the veins, the mode of distribution of the larger branches, and the manner in which their sheaths are formed.

which traverse the substance of the gland, some ramifying in its anterior, and others in its posterior half. These branches are of considerable size, and open directly into the trunk of the vein itself. They are not in general accompanied by an artery, but are contained in a sheath, which is common to them only, the thickness of which is much greater than the thin walls of the vein, and about half as thick as that which encloses the trunk of the vessel. These branches traverse the substance of the organ from the point at which they arise from the trunk, to either extremity, giving off from either side two different sets of branches. The first of these are of large size, and are derived from either side of the vein. They ramify in an arborescent manner through the substance of the organ: the others are numerous small vessels, which open into the floor of the vein by many minute lancet-shaped openings, (the so-called stigmata Malpighii). These also ramify in a similar manner through the substance of the pulp.

The distribution of each branch of the veins is limited, like the arteries, to the supply of a particular part of the organ. On injecting each of these branches, the material introduced is confined solely to that part of the organ which the vein supplies; in no case does the injected matter make its way to any other part of the organ. The injection, also, in no case returns by a distant venous branch, and but rarely by its accompanying artery. When the injection does return by the artery, its amount is very limited in quantity. These results show that the distribution

of each venous branch, is like that of each arterial branch—limited to that part of the organ which that branch supplies, in no case returning by any neighbouring branch.

I shall now consider the minute anatomy of these smaller veins.

The *veins* of the spleen are much larger, and far more numerous than the arteries; so much so, that when both sets of vessels have been injected, the organ appears to be chiefly made up of veins.

These vessels arise in three different ways,—1st. as continuations of the capillaries of the arteries;—2ndly. By intercellular spaces, through which the veins communicate with each other; and 3rdly. By distinct cœcal pouches.

1st. The delicate capillary vessels of the spleen at some distance from the point where the veins join them, are of an equable diameter; but almost immediately after their junction with a vein, it *suddenly becomes wider and more spacious*, so as to present a narrow, elongate, funnel-shaped form, the narrow end being connected with the capillaries, the broader end with a branch of the vein. More rarely, one or two capillaries terminate by emptying themselves into the sides of a wide and rounded end of a small vein; whilst others also terminate in branches of veins, which retain for a time the *same* diameter (See fig. 21). Of these three methods of the termination of the capillaries, and the origin of the veins, the first is by far the most common.

Although, however, such is the actual connexion of

the smaller veins with *some* of the capillary vessels, other capillary vessels exist, and these are somewhat numerous, which cannot be demonstrated as having any connexion *directly* with the primary venous branches: these vessels, which form part of the capillary network of the gland, and the walls of which are but formed of epithelium, become lost in the substance of the pulp, the delicate walls of which they were composed becoming lost to view; so that the blood must traverse spaces between the elements of the pulp tissue of the organ, before entering the smaller branches of the veins.

FIG. 24.*

* Arrangement of the veins on the surface of the spleen in the sheep.

2ndly. The veins originate as 'intercellular spaces,' by which they communicate with each other. It has been stated by Müller and Krause, that the veins of the spleen form *numerous anastomoses* with each other; this I have *never* been able to demonstrate, after the most repeated and careful injection and microscopic examination. (Fig. 24). *Occasi-*

Fig. 25.*

onally, on the surface of the spleen, the large branches of the veins anastomose with each other, but this is by no means a frequent occurrence. More frequently they have the following arrangement, (fig. 25.) When

* Arrangement of the veins in the interior of the spleen in the sheep.

the veins have become reduced in size from the 500th to the 1000th of an inch in diameter, they pass for a short and varying distance in the substance of the pulp, when their walls, which are exceedingly thin and delicate, and are formed merely by the junction of the epithelial cells, *become gradually lost to view*, and the injected material filling the vessels, either terminates *abruptly* at that point, or is *extravasated in a finely divided state* among the elements of the pulp tissue of the organ. These vessels terminate then in the substance of the pulp in such a manner, that the whole of the constituents of the blood traversing them must pass through spaces between the elements of this tissue, no *direct* communication by means of tubes with membranous parietes, existing between the smaller branches of the veins. These interspaces are analogous to the intercellular passages seen in the lower tribe of plants, by which the nutritious juices are conveyed to different parts of their structure. They bear, however, a still greater analogy with the same passages in the lower invertebrata, by means of which their *venous circulation* is mainly carried on. This peculiar and very interesting origin of the veins in the manner above mentioned, is by far more frequent than either their *direct* connexion with the capillary vessels, or their still more rare origin by blind cœcal extremities. Its physiological relations are, however, still more important than the mere anatomical fact, as a ready explanation is now afforded of the *constant occurrence* of the diffusion of blood, and of its disintegration in the pulp tissue of the organ.

3rdly. The veins originate by distinct cœcal pouches,[1] (fig. 26). The origin of the veins by cœcal pouchings is not frequently to be observed, and their form and arrangement somewhat differ.

FIG. 26.*

They consist of elongate vessels of equable diameter, but which vary considerably in length, placed on the sides of the smaller branches of the veins, and terminating by a distinct and well-marked rounded extremity. Their structure does not quite correspond with that of the smaller branches of other veins; for, besides their epithelial wall, the tube is also formed of a finely delicate

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[1] Dilatations and bulgings of the branches of the splenic vein have been before noticed by KRAUSE, POELMANN, HYRTL, and more lately by ECKER.

* The origin of the veins by cœcal pouches is shown in these figures.

external homogeneous membrane, which extends to the extreme end of the tube. These vessels are of rather large size, having a diameter about the 250th of an inch, and are generally situated on the side of a vein *just before* the smallest branches are given off. *Still more rarely*, these cœcal pouchings have a flask-like form, being narrow at their point of connexion with the canal of the vein, and then becoming dilated into a broad receptacle, having a rounded extremity. *Occasionally*, the *larger branches* of the veins exhibit a peculiar form; they sometimes terminate by a rounded end, from the sides or extreme point of which *one or more* branches are given off, the diameters of which are very *much less* in size than the broad rounded end of the trunk of the vessel itself. The existence of these peculiar vessels is interesting, not only as an anatomical fact, but from their relation in explanation of the physiology of the organ as regards its use as a diverticulum of the blood.

The size of the veins is *very considerable*, and this is not only the case with the larger trunks, but also with the smallest branches, especially when compared with the smallest ramifications of the artery. The following measurements represent the mean average diameter taken of a vein, from its commencement to its joining a neighbouring trunk, and will best illustrate the rapid increase in the size of these vessels. The two small veins forming the branch had each a diameter of the 1250th of an inch. At their junction, the vein had suddenly increased in size to the 500th of an inch, a little farther, the same branch having received no acces-

sories measured the 250th of an inch, the vessel, from its peculiar form, increasing in diameter during its passage; whilst the junction of two such vessels to form a larger branch had a diameter of the 180th of an inch. Such examples of extreme and rapidly increasing size in the smaller veins of an organ, as far as I am aware, are not to be found in any other part of the animal body, and they form a most striking contrast to the arteries, which are, as compared to these vessels, very inconsiderable. This large size of the veins, even at their extreme ramifications, taken in connexion with the extreme variations in the amount of blood contained in them, and supported as they are by a highly elastic and distensile framework, exhibits all the evidences of design, if we consider the organ as capable of acting at certain periods as a reservoir for blood.

The structure of these *smaller veins* is exceedingly delicate, consisting merely of the approximated epithelial cells, which are of a fusiform or spindle shape, containing in their centre a small oval nucleus. These delicate vessels, when not distended by injection or by blood, have their sides so closely approximated as to form a tube one fourth the size that it attains when in a distended state, their sides being here and there protected by delicate fibrous membranes, which form the finer trabeculæ of the pulp.

I come now, lastly, to consider the *situation* of these *smaller veins*. These vessels have two most important relations with the constituent parts of the spleen, one set being confined to the structure of the *pulp tissue*, the other set to the *Malpighian bodies*.

The relation of the smaller veins to the *pulp* has already been briefly adverted to. They commence by receiving blood from the capillaries, or from the intercellular spaces, and joining with branches of somewhat similar size at acute or right angles form trunks of larger size, which receive both larger and small branches in a similar manner. These small veins are completely surrounded by the elements of the pulp tissue of the organ, and are only separated from them by the thin and delicate epithelial wall of which they are constituted. The *smaller veins* have an equally important relation with the *Malpighian bodies*, a relation which, as far as I am aware, is not noticed by any observer, and one which assists in explaining the functions of these parts of this remarkable organ. Each Malpighian body is completely enclosed by an imperfect capsule formed of the small primary veins. These vessels, which are of large size, commence on the surface of each body throughout the whole of its circumference, and, radiating from the central part, join with similar branches, either on the surface or towards the circumference; lastly, these larger veins empty themselves into the neighbouring ones of the pulp. If we take into consideration the interesting fact of the variation in the size of these bodies under certain conditions,—their enormous increase after digestion, their extreme diminution during starvation,—the relation of the smaller veins to them would appear to act as the channel by which the secretion formed in these glands is carried into the circulation.

The above description applies simply to the veins in the human subject, and in most of the mammalia the same disposition exists; but in others, as in the ruminantia, and in the pachydermata, some differences are observed in their structure and arrangement deserving of notice.

In the ruminantia and pachydermata, the splenic vein, on its entering the organ, is of very considerable magnitude, and presents the appearance of a large excavation or sinus, running throughout its substance, the walls of which are of such extreme tenuity that the red colour of the pulp, and the outlines of the Malpighian bodies, are seen through it. This vein soon divides and subdivides into branches of somewhat smaller, though still of very considerable size, on the walls of which large, and also many minute orifices (stigmata Malpighii) are to be observed. Some of these veins are of such extreme size, and at the same time present such thin walls, that at first sight one might be led to suppose them as simple excavations in the substance of the organ, or as 'venous sinuses;' such, however, is not the case, for one may trace, by careful examination, a smooth shining surface as forming their boundary, and a covering of fusiform epithelial cells. Moreover, after a successful injection the outlines of the vessels are marked out, from the limit to which the injection extends, and which does not encroach upon the surrounding parts; the smaller veins also give off from their sides large and smaller branches, and finally terminate in the pulp tissue of the organ in an

arborescent manner, spreading out into still smaller and more minute branches, which do not, however, present a flexiform interlacement. The existence of venous sinuses or cells I have never observed either in man or in the mammalia. The structure of the veins also require some notice, as they materially differ from the same vessels in the human subject.

In the larger venous trunks, (fig. 27,) their walls

FIG. 27.*

consist of a *thick* membrane formed by the interlacing of numerous fine trabeculæ, which exist in the form of anastomosing fibres, or of fibrous membranes, the interspaces between which (fig. 28) are either traversed by finer fibres, or a homogeneous membrane, or

* A portion of the trunk of the splenic vein in the sheep at its entrance in the spleen, showing the wall to be composed of interlacing trabeculæ, the interspaces between which are closed by a fine homogeneous membrane.

they exist as the apertures of varying-sized venous canals. These fibres are composed partly of the

FIG. 28.*

white fibres, but chiefly of the yellow elastic kind, which latter exist in really enormous quantity. A layer of longitudinal muscular fibres, with their oval elongated nuclei, may also be observed as composing part of their wall.

In the *secondary subdivisions* of the veins, (fig. 29,) the interlacing trabeculæ are less numerous and more delicate than those found in the larger veins; the interspaces formed by their junction are consequently larger, and these are again crossed by finer single fibrillæ, or by a fine homogeneous membrane. The structure of these fibres is precisely similar to those

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* A small portion of the wall of one of the primary venous trunks, more highly magnified to show the structure of the membrane between the trabeculæ.

composing the larger veins. A few muscular fibre cells are also to be observed.

FIG. 29.*

The *tertiary subdivisions*, (fig. 30,) which compose the smallest vessels capable of being separated by the scalpel, consist of an exceedingly delicate homogeneous membrane, sparingly crossed at irregular intervals by a few delicate fibres, but containing no muscular fibre cells on their wall.

The finer microscopic veins consist simply of a homogeneous membrane lined by epithelium, and these, again, are succeeded by interspaces in the pulp tissue, lined simply by delicate, elongate, spindle-shaped epithelial cells, the only structures which serve to separate the blood directly from the pulp.

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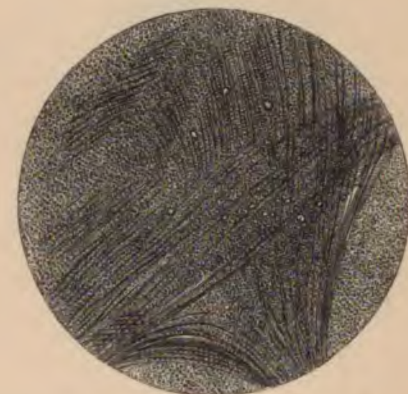
* A portion of the wall of one of the secondary subdivisions of the vein acted upon by acetic acid to show the large number of elastic fibres composing the delicate trabeculæ which line the vein. Magnified 300 diameters.

I believe that in some cases even epithelium does not exist on the walls of some spaces traversed by the blood.

FIG. 30.*



ON THE BLOOD OF THE SPLEEN.

The entire absence of any excretory duct to serve in carrying off, as in most glands, the matters changed, or formed in the spleen, has, at all times, led most physiologists to believe that the emerging blood, or lymphatic vessels, served the purpose of those tubes; and that, consequently, *an accurate comparison* of the composition of the blood *returning* from the organ, as compared with that which *enters* the gland, as well as an accurate analysis of the lymph, would lead to a solu-

* A portion of the wall of one of the tertiary subdivisions of the vein, showing the extreme delicacy of the fibres, and homogeneous membrane which constitute it.

tion of the *function* of this complicated organ. And if the extreme variations in the size of the organ, the large size of its bloodvessels, and their ever-varying state of fulness, be considered, such a belief was not founded on conjecture alone. As far as I am at present aware, Beclard[1] was the first to investigate this important point. His observations I have referred to previously. More lately Dr. Funke[1] (the results of whose examinations I have also mentioned) arrived at conclusions *exactly opposite* to those of Beclard. He himself admits that 'his analyses are entirely unaccountable; they have hardly given foundation to any certain facts.'

The results of the investigations that I am now àbout to mention, form by far the most important part of my subject, and they will, I think, unquestionably prove, in connexion with the minute anatomy and chemical composition of the spleen, the function which this organ performs. The investigations on the blood of the spleen are the results of microscopic examination and chemical analysis; in order to determine the former, several hundred examinations have been made on the blood of various animals, whilst the latter have been derived from a hundred and eleven analyses of the blood obtained from eighty healthy horses. The method in which the investigations have been conducted, was the following. In order to determine the *peculiarities* of the splenic venous blood, a comparison was first instituted between it and the

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[1] See *Historical Introduction.*

blood *entering* the organ, and certain differences being observed to exist in all cases, it was now compared with the blood from the general venous system (the jugular vein), as it was conceived that although it might differ from the arterial blood *entering* the organ, still it might *not* differ from *other venous* blood; certain differences were, however, observed *between these;* and, lastly, it was compared with blood obtained from the *portal venous system* (mesenteric vein), when the same marked differences were observed here also. The results of these experiments could but lead to one conclusion, viz., that the *differences* observed in *the first instance* between the *entering* and *emerging* blood, could only be ascribed to the spleen, as far as the changes produced in the blood are concerned. Having arrived at these conclusions, it was determined in the next place to ascertain, first, are the *differences* above mentioned in the splenic venous blood, to be found at *all periods of life?* second, are they found to vary during the period of the *digestive process?* and thirdly, do these differences become altered or modified, according to the *state of nutrition* of the animal, or under any other conditions?

If the conclusions at which I arrived from the development of the spleen are correct, deducing the *function* of the organ to be at its *maximum* when it attains *its largest* size, the differences observed in the splenic venous blood, which are peculiar to this blood, and which indicate *the function* of the organ, should be *most marked* during the periods of the *greatest activity* of the organ, and which are, as I have

shown, during the whole period of life, from birth to adult age, more particularly after the completion of the digestive process, but varying also according to the state of nutrition of the animal. The following investigations will, I think, unquestionably prove not only that the differences observed in the splenic venous blood are *constantly found* during the whole period of life, but what is infinitely of greater importance, that these differences present *very considerable variations* at the period of *ingestion of food;* and are *also* greatly modified according to the condition of the animal, as regards its state of nutrition.

Before considering either the microscopical appearances, or chemical composition of the blood, I shall mention the *quantity* that could be obtained from the organ *at different periods* and *under different circumstances*, *its rate of coagulation*, *specific gravity*, and other general characters. In order to determine the *amount* of blood that could be obtained from the veins of the spleen in the horse, and to discover the causes which modify its states of repletion and emptiness, a series of experiments were had recourse to; they are here appended in a tabular form, and are arranged under certain special heads. The conditions under which the amounts of blood appeared to vary, were—

1st. According to the period of the digestive process.

2nd. According to the state of nutrition of the animal.

3rd. According as the respiration is impeded, or not.

4th. After the introduction of fluids.

5th. According to the amount of blood *taken from*, or *introduced into*, the vascular system.

1st. and 2nd. Quantity of Blood obtained from the Veins of the Spleen in the Horse, during the Digestive Process and during certain States of Nutrition.

State of Nutrition.	Period *after* Feeding.	Quantity obtained.
Well fed	4 hours.	2808 grains.
Well fed	9 "	2225 "
Well fed	10 "	1529 "
Well fed	10 "	1500 "
Well fed	12 "	1371 "
Well fed	12 "	2369 "
Well fed	16 "	2641 "
Well fed	16 "	2446 "
Well fed	16 "	2415 "
Ill fed	16 "	816 "
Ill fed	16 "	371 "
Starved	16 "	60 "
Starved	16 "	50 "
Starved	16 "	75 "
Well fed	24 "	895 "
Well fed	24 "	900 "
Well fed	48 "	724 "

3rd. The amount of Blood obtained from the Spleen after impeded respiration.

A well-fed healthy horse was placed under chloroform, the inhalation lasting half an hour, during which time considerable difficulty in the respiratory process was manifested. The spleen was found gorged; 9000 *grains* of blood were obtained from the splenic vein.

4th. The amount of Blood obtained from the Spleen after the introduction of fluids, or from suspension of the same.

Experiment 1.—A horse was fed, but *did not drink* for 30 hours, 295 grains of blood were obtained from the spleen. The organ was small, contracted, and dark coloured. The cœcum (or water-gut) contained only a *very small* quantity of fluid.

Experiment 2.—A second horse drank for 30 hours preceding death as much water as he liked, he drank a bucketful *three hours* before death; 764 grains of blood were obtained from the spleen, which was large, congested, and of a light red colour. The cœcum contained a *very large quantity* of water (two bucketfuls).

This experiment appears to show that the absorption of water does not take place so rapidly (at least in horses) as is usually believed; and although a threefold increase in the amount of blood obtained from the spleen was found in this experiment, still less was found than I expected, and that, I believe, simply from the non-absorption of the fluid, as the next experiment shows.

Experiment 3.—A horse drank two bucketfuls of water *nine* hours before death; 1800 *grains* of blood were obtained from the splenic vein. In this experiment a large amount of the water introduced was absorbed, as only three parts of a bucketful of fluid was found in the cœcum.

5th. *Experiments to determine the amount of Blood obtained from the Spleen, under the varying conditions of the introduction of fresh Blood into the Vascular System, or after its withdrawal from the same.*

Three donkeys being fed and watered to the same amount, and precisely at the same time, *nine* hours before the following experiments were performed, one of them had a quart of blood transfused into the *jugular vein from* a second donkey. From the spleen of the former (which was the poorer animal), 210 *grains* of blood were obtained, from the latter, *fifty* grains *only*. A third donkey had about a quart of blood transfused into the mesenteric vein; the amount of blood obtained from the spleen in this case was 312 *grains*.

The results from these experiments show, that the quantity of blood that can be obtained from the spleen *varies considerably* under different circumstances. That during digestion, the greatest amount exists in the organ about *sixteen hours after* the introduction of food, about the period when the digestive process has arrived *at its completion*, and the new material is introduced into the blood. The smallest amount, *forty-eight hours* after digestion, when the new material has, probably, been expended in the various processes of nutrition, secretion, and excretion. It is also to be observed, that the amount of blood contained in the organ *varies* according to the *condition of the animal*, as regards its nutrition, although examined *at the*

same period after feeding, being *small in quantity* in ill-fed animals, whilst in those *that are starved*, little more than *a few grains* could ever be obtained.

Nor is it after the introduction of *solid food* alone, that the *increased* amount of blood in the spleen is found; for, as is seen in the preceding experiments, the introduction of fluids, more especially where absorption proceeds rapidly, and where, consequently, the vascular system becomes again soon filled, is followed by a considerable increase in the amount of blood in the spleen; whereas a diminution in its amount is observed, under a contrary condition. The experiments on the withdrawal of blood, or the introduction of blood, by transfusion, either in the portal or general venous system, and which are simply modifications of those experiments where fluid nutriment is introduced or withdrawn from the vascular system, are attended with precisely similar results; namely, a considerable increase in the amount of blood contained in the spleen when the vascular system is replete, or over-distended, a great diminution being, on the contrary, found where these conditions are reversed.

The spleen, however, appears to act as a reservoir for blood under other conditions than those above mentioned, conditions not dependant, in any way, upon the *amount* of fluid in the vascular system, but which are rather dependant upon the abnormal circulation of the blood. Under these circumstances, where obstruction to the circulation is a consequence of *impeded respiration*, and where, probably, extreme congestion of

the large vessels would be attended with dangerous results, the spleen becomes distended with the enormous amount of blood that it contains.

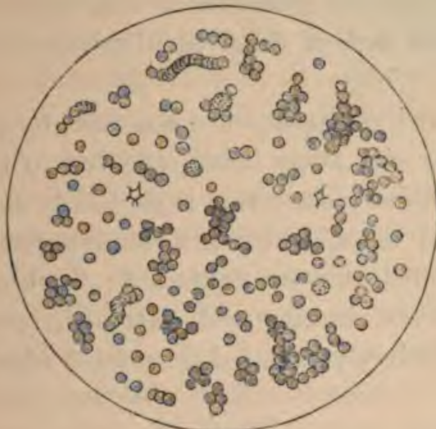
It is not from experiment alone that similar conclusions may be drawn: the effects of long continued disease in certain organs (the heart and liver), attended with obstruction to the circulation of the blood, are, as is well known, in all cases accompanied with considerable enlargement of the spleen, and with distension of its vessels with blood.

The blood of the splenic vein coagulates in a precisely similar manner to the blood either from *the aorta*, or *jugular vein*. In some cases, the whole of the blood coagulated in a *uniform mass*, without any separation of the serum. In other cases, it separated into serum and crassamentum; the former of which soon gelatinized into a jelly-like mass, which in a few hours *again* became liquid. The same peculiarities were, however, also found in venous blood, obtained from other sources, and also in arterial blood.

The *specific gravity* of splenic venous blood varied between 1050·9 and 1074·2, being rather *less* than the specific gravity of the *arterial blood* from the same animal, which was, as compared to the above numbers, 1052·1 and 1073·8.

With regard to the other *general characters* of this blood, viz., its colour, taste, smell, and alkaline reaction, no appreciable differences could be remarked.

FIG. 31.*



MICROSCOPIC EXAMINATION OF THE SPLENIC VENOUS BLOOD.

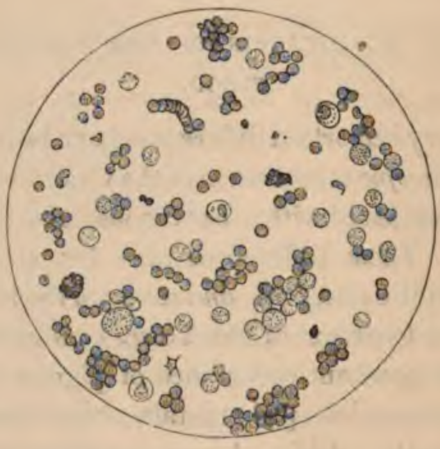
Many very important differences have been observed in the *microscopic examination* of the venous blood of the spleen, as compared with other venous and arterial blood (fig. 32). These differences are—1st. Considerable variation in the *size, form, and colour* of the blood discs. 2ndly. The existence of blood discs contained in cells. 3rdly. The constant occurrence of pigment granules, or masses, or rod-shaped crystals, either free, or contained in cells. 4thly. A very considerable number of *colourless* corpuscles. As far as I have been able to ascertain, these peculiarities are not to be observed in the blood of any other organ; they may then, I think, consequently be looked upon as *peculiar* to the splenic

* Arterial blood from the carotid artery of the horse. Magnified 350 diameters.

venous blood, and as such, may assist in throwing some light on the function of this organ. I shall now consider each of these peculiarities somewhat in detail.

1. The red corpuscles are observed to *vary somewhat in their size*, many being observed to be smaller than the ordinary size; this is especially seen in the single blood discs, which are floating freely in the serum in which they are contained: *the form* of these discs is either circular and flattened, or else they present a distinctly indented or serrated edge, or, more

Fig. 32.*



rarely, they present an irregular or wrinkled shape, which has no particular form; their colour is either that which is usually observed, or occasionally, many

* Splenic venous blood from the splenic vein of the horse, showing a large number of colourless corpuscles, brilliant red particles of hæmatin, as well as blood discs contained in cells.

are of a *very pale red tinge*, or even colourless, as if partially or completely deprived of their *hæmatin*. These discs arrange themselves as in other kinds of blood, they exist either singly, are collected into nummular rows, or are arranged into heaps or masses of varying size and form.

The *effects of re-agents* on the blood discs act in no respect differently to what is observed in other kinds of blood. Acetic acid *completely* dissolves them.

2. *Occasionally* may be observed in the splenic venous blood, blood discs included in cells. These structures are precisely similar to what is observed in the pulp, consisting of one or more unchanged blood discs, enclosed in a distinct cell, which is in some cases furnished with a nucleus. At other times, the included blood discs do not present their normal appearance, they are darker, more refractive, and of an irregular form.

3. One of the most remarkable peculiarities in the splenic venous blood is the *almost constant* existence of numerous pigment granules, or masses, or rod-shaped crystals, which either exist free, or are contained in cells. The pigment *granules* exist as numerous exceedingly minute fine granules of varying size, but of no regular form; they are generally either of a dark *black*, or of a dark *reddish black* colour, unacted upon by caustic alkalies, acetic acid, alcohol, or æther; they are found either floating about free in the blood, or more rarely are contained in exceedingly delicate cellular envelopes; they occur either *singly*, or are aggregated into small heaps, of varying size. This

pigment, or colouring matter, as commonly exists not as granules, but in large *masses*, of a *black*, or *reddish black*, or *blood red* colour, behaving in a precisely similar manner with re-agents as the granules above-mentioned. Still more rarely are seen numerous colourless vesicles, about twice the diameter of the blood discs, which contain in their interior, either one, two, or more, elongate rod-like bodies, of a *red* or *yellowish red colour*, and apparently of a crystalline form. These latter are dissolved by the action of acetic acid.

The whole of the above-mentioned coloured pigment and crystalline bodies appear to have an intimate relation one with another, and apparently consist of a substance allied most intimately to the hæmatin of the blood, or to what has been called by Virchow hæmatoidin.

In many instances, an accurate examination will enable one to make out, without any difficulty, the various transitions in the formation of these granules. The above-mentioned blood discs enclosed in cells, present in some cases their normal appearance, in others, the included discs have become darker, more refractive, their form is more irregular, they have become indented and wrinkled up; whilst, finally, many cells are seen, in which the enclosed blood globules have become converted into dark red or black pigment granules, or more rarely, into yellowish, or yellowish red, rod-shaped crystalline bodies.

4. An equally remarkable peculiarity in the venous blood of the spleen is the *constant existence* of a *large*

number of *colourless corpuscles* (fig. 33). So numerous are they in some cases, as to form a very large part in the constitution of the blood, as compared to other venous or arterial blood. These corpuscles are of *two kinds.* 1st. Either simple circular-shaped nuclei, equal in size, or rather larger than the blood discs; they are pale in colour, and consist of a quantity of exceedingly minute granules, contained in a delicate cellular envelope, some of the contained granules presenting, in some cases, a dark refractive appearance. 2nd. Some of these corpuscles are of *much larger size*, equal in number those above-mentioned, and when *unacted upon* by acetic acid, present a similar structure with them. They are globular, and vary in size from the 2500th to the 3333rd of an inch in diameter; those above-mentioned, from the 3333rd to the 5000th of an inch. These *corpuscles*, although presenting in most cases no difference in their structure, are very differently affected by *certain re-agents.* On the application of acetic acid (fig. 34), the *smaller nuclei* present a more dark and refractive appearance, and

FIG. 33.*

FIG. 34.†

* The colourless corpuscles of the splenic venous blood, more highly magnified.

† The colourless corpuscles acted upon by acetic acid to show the apparent nucleus which they contain.

the central particles become more distinct. The *larger corpuscles*, on the contrary, are now seen to consist of an outer membrane, containing in its centre a nucleus, with dark and highly refractive margins. The nucleus varies very considerably in its form; in some cases it is circular, and contains a nucleolus; in others, its margins are irregular and indented; sometimes it presents traces of a fissiparous division, whilst lastly, in some a bipartate, tripartate, or even a quadripartate division has completely been effected. It may now be asked, are these corpuscles *peculiar* to the *emerging blood* of the spleen, or do they resemble in any respects those of other venous and arterial blood, and of the lymph? From very repeated and careful examination, I may state that they do not differ in any respect from the colourless corpuscles of other blood, excepting in their *much greater number*. They differ from the corpuscles of the lymph in this respect, that this latter fluid contains *many more* of the simple circular nuclei, *few* of those larger kind in which the nucleus presents the appearances that I have above-mentioned being found. Lastly, do they present any resemblance in their structure to the cellular elements of the spleen pulp? Their resemblance to the parenchyma cells is so exact, that this fact, coupled with their great increase of number in the *emerging blood*, as well as the relation of the commencing veins to the pulp, cannot but lead to the inference that they are derived *from this organ* during the transit of the blood through it. It has very lately been asserted by Dr. Bennett that the *fissiparous division of the nuclei*, seen in the

corpuscles above-mentioned, are the primordial steps to the formation of the red blood discs in these corpuscles, and that consequently the spleen, the other ductless, as well as the lymphatic glands, are considered by him as 'the secretors of the blood.' The observations above-mentioned, as well as the results of the chemical analyses of the blood, will, I think, negative this conclusion.

The next point to determine was, whether the peculiarities already mentioned in the splenic venous blood *were constant*, and if, under certain conditions, any marked differences could be observed. In *all cases* in which the blood has been examined, the above described differences were noticed, excepting the occurrence of the *blood globules contained in cells*, which were only *rarely* seen. In the numerous experiments performed on the blood of animals fed at certain periods, *no difference* ascertainable *by the microscope* could be detected, as far as the variation in colour of the blood discs, the number of coloured granules, and colourless corpuscles, were concerned.

ON THE CHEMICAL EXAMINATION OF THE BLOOD.

The results which I have obtained from one hundred and eleven *separate analyses* of the blood of the spleen are of the very highest importance, and will assist, I think, in clearly deducing the function of this mysterious organ. When the present investigations were first commenced, it was thought advisable that the blood to be analysed should be obtained from *living* horses, placed under the influence of chloroform; and such an experiment was had recourse to, and most satisfactorily in one instance. The great difficulty to respiration, however, encountered by the animal gave rise to *extreme venous congestion* of the organ, and consequently a fair sample of *splenic blood* could not be obtained. Under these circumstances, the blood to be analyzed was drawn from the vessels (the splenic vein having been previously tied) in every instance *immediately* after death.

The results that were obtained from these investigations on the emerging blood of the spleen, as compared with the arterial blood entering the organ, as compared also with the blood from the general venous system (jugular vein) and portal system (mesenteric vein), have shown that this blood presents the following marked and *constant* peculiarities. It contains *less solid matter* than arterial or other venous blood; it contains *far less* blood globules; a *considerable increase* in the amount of *albumen* and *fibrine;* it

contains more fat; a variable amount *of iron;* whilst, lastly, *the serum* presents in all cases a *dark reddish tinge.*

If the subjoined analyses show that these peculiarities are well marked and constant, it cannot but, I think, be admitted, that not only are they peculiar to the venous blood of the spleen, but that they represent the effect that the organ has upon the arterial blood during its passage through it, or, in other words, they represent the function of the organ. These, however, are not the only results obtained from these analyses; for, in the next place, it was necessary to determine if these peculiarities were constant during the various periods of life, and if they were in any way modified at the varying periods of the digestive process, or according to the state of the general nutrition of the body.

I shall now consider each of the peculiarities of the venous blood of the spleen somewhat in detail.

1. The amount of *solid matter* in the splenic *venous* blood is *less* than in the arterial blood entering the organ, or in other venous blood.

TABLE I.

Analyses of Aortic, Jugular, Mesenteric, and Splenic Venous Blood, for a Determination of the Solid Matter and the Water. In 1000 *parts.*

		AORTIC.		JUGULAR.		MESENTERIC.		SPLENIC.	
No. of Experi-ments.	Hours fed before Death.	Water.	Solids.	Water.	Solids.	Water.	Solids.	Water.	Solids.
1	6	......	......	790·7	209·3	......	... ..	812·20	187·80
2	6	......	......	770·0	230·0	......	......	786·8	213·2
3	8	......	......	......	......	801·4	198·6	846·2	153·8
4	8	......	......	......	......	856·0	144·0	883·4	116·6
		740·02	259·98	814·03	185·97	......	......	783·06	216·04
5	9	756·72	243·28	805·48	194·52	......	......	818·14	181·86
		......	......	......	......	......	......	812·25	187·75
		783·9	216·1	784·9	215·1	......	......	727·8	272·2
	Chl.	765·8	234·2	750·4	249·6	......	......	726·7	273·3
6	9½	781·0	219·0	785·2	214·8	......	......	715·5	284·5
	Chl.	782·7	217·3	......	......	......	......	......	......
		794·0	206·0	......	......	......	......	......	......
7	16	740·0	260·0	782·5	217·5	......	......	798·8	201·2
8	16	719·1	280·9	755·0	245·0	......	......	755·0	245·0
9	12	721·6	278·4	......	......	......	......	739·6	260·4
10	12	783·79	216·21	800·15	199·85	......	......	826·04	173·96
11	24	768·01	231·99	795·8	204·2	......	......	799·4	200·6
12	12	756·7	243·3	......	......	......	......	814·5	185·5
13	16	731·11	268·89	813·82	186·18	......	......	812·02	187·98
14	16	830·9	169·1	......	......	......	......	886·88	113·12
15	4	776·57	223·43	......	......	......	......	823·47	176·53
16	...	748·00	252·00	......	......	......	......	760·00	240·00

The accompanying table contains all the experiments (forty-nine in number) that have been made in order to ascertain this point. In sixteen experiments, including that in which chloroform had been pre-

viously administered, and where the organ had become engorged with blood, the average amount of solid matter contained in 1000 parts of arterial blood is 235·2. In twelve experiments on the jugular venous blood, the amount of solid matter is 212·3 per 1000; and in nineteen experiments on the blood from the splenic vein, the average amount was 199·0 per 1000. If, on the contrary, the experiments under chloroform are excluded in each case, as they should be, in order to draw accurate conclusions, the amount of solid matter in the splenic venous blood is *still further diminished*, the amount being in the arterial blood 239 per 1000; in the jugular venous blood 201; whilst in the splenic it is only 187·1 per 1000.

The results obtained from these experiments could only lead to the above-mentioned inference—viz., that the venous blood of the spleen contains, under nearly all circumstances, in the healthy and natural condition of the organ, less solid matter than either arterial or other venous blood. With regard to the period when the amount of solid matter presents its *greatest increase* or *diminution*, no positive conclusions can as yet be formed; probably the number of experiments is too small to afford any accurate data.

2. The amount of crassamentum in the splenic venous blood is diminished, the serum increased.

It would be conceived from the above-mentioned results, that the relative amounts of *serum and clot* would *also differ* in the three kinds of blood, as the water and solid matter of the blood present such

marked differences, and such is found to be really the case. In two experiments on arterial blood, the average amount of the cruor in 1000 parts of blood was 159·5: in four experiments on the jugular venous blood, 141·0 in 1000; and in the same number made on the venous blood of the spleen, the average amount was 95·12 per 1000. From the circumstance of each of these experiments (though few in number) presenting, in each case, *a similar result*, it may, I think, be correctly deduced, that the amount of crassamentum contained in the venous blood of the spleen is considerably diminished in quantity, as compared either with arterial or other venous blood, whilst the amount of serum is increased.

3. The *red corpuscles* present a very considerable *diminution* in the splenic venous blood, varying however, in amount, according to certain conditions. (*See* TABLE II.)

The determination of the amount of the blood corpuscles in the splenic venous blood, as compared with the arterial blood entering the organ, and with other venous blood, is one of the most important points in the present analyses, and the results of which will afford the most accurate data that can be derived to ascertain the truth of the theories that have lately been made regarding the function of the spleen; some authors having asserted that the blood globules are *formed there*, others that they are *destroyed there*, whilst, lastly, some believe that the blood globules are neither formed nor destroyed there. In order to determine, with the most extreme accuracy, this very interesting

TABLE II.

Analyses of the Composition of Aortic, Jugular, Mesenteric, and Splenic Venous Blood.

No. of Experiment.	State of Nutrition.	Hours fed before Death.	AORTIC.			JUGULAR.			MESENTERIC.			SPLENIC.		
			Albumen.	Fibrine.	Red Corpuscles.	Albumen.	Fibrine.	Red Corpuscles.	Albumen.	Fibrine.	Red Corpuscles.	Albumen.	Fibrine.	Red Corpuscles.
1	Well fed	4	41·30	4·96	156·13	...	...	...	...	...	...	50·23	5·37	109·56
2	do.	6	...	...	...	53·60	2·36	162·00	...	...	...	83·30	3·21	102·00
3	do.	6	...	...	...	56·40	4·32	139·20	...	...	...	63·30	6·67	108·20
4	do.	8	...	...	...	...	...	...	39·4	3·23	157·5	53·5	2·80	94·6
5	do.	8	...	...	...	...	...	...	80·9	7·5	63·6	81·3	8·06	35·8
6	Ill fed	10	...	...	...	53·0	5·6	136·4	...	...	...	58·20	10·88	85·84
7	Well fed	10	31·20	2·53	188·4	...	...	...	...	...	...	78·00	11·53	60·00
8	do.	16	39·26	1·79	104·80	...	...	...	...	...	...	41·23	4·31	27·93
9	Starved	48	40·9	2·1	173·4	...	...	...	...	...	...	35·3	2·5	173·2
10	Well fed	48	45·7	·78	91·5 0	54·4	6·23	125·40	...	...	...	61·4	10·3	91·7

point, I may mention, that every method that for the last twenty years has been adopted for the separation of the blood globules from the other elements of the blood has been repeatedly tried, and that *method* was had recourse to in these experiments which afforded the most accurate results. In the accompanying table will be found *nineteen* experiments, in which the blood globules have been separated from the other elements of the blood, and in no single instance is their *amount increased* in the venous blood of the spleen; on the contrary, this blood presents a very *considerable diminution* of the blood corpuscles. In five experiments on the arterial blood entering the spleen, the average amount of blood corpuscles in 1000 parts of blood was 162·2. In four experiments on the blood from the jugular vein, the amount was 142·0 per 1000, whilst in ten experiments on the splenic venous blood, the average amount was 88·5 per 1000. In two experiments, in which the *mesenteric* blood was analysed and compared with the splenic blood of the same animal, nearly *double* the amount of blood corpuscles was found in the former. The only conclusion that could be derived from these experiments was, that the emerging blood of the spleen contains *little more than one half* the amount of blood corpuscles, as compared with the blood which *enters* the organ, or with other venous blood. The great importance of this fact led me, in the next place, to observe if this diminution of the blood corpuscles was *constant* throughout the *various periods of life*, and if any marked modification was observed, either at the *various periods of digestion*,

or according to the *state of nutrition* of the animal. The above-mentioned experiments were performed upon horses *of every age*, and although *slight variations* were observed in the amount of the blood corpuscles in the splenic blood, probably depending upon other causes, still the same principal fact is observed in each case, viz., *a considerable diminution* in their number. It has been before observed that the *amount of blood* contained in the spleen differs, according to the various stages of the digestive process; the same difference is also observed as regards the amount of the *blood corpuscles*, the *greatest diminution* being observed about sixteen hours after the ingestion of food, when the amount of blood globules was only 27·93 per 1000, whilst, on the contrary, at an *early period* after the ingestion of food (four and six hours), and consequently before digestion can have been completed, and the new material become converted into blood, the amount of blood globules contained in 1000 parts of splenic blood were respectively 109·56, 108·20, and 102 per 1000. (See experiments 1, 2, and 3.) The most marked variations appeared however to depend *chiefly* on the state or condition of the animal, as regards its general nutrition. The number of the blood corpuscles being *considerably diminished* in the splenic venous blood of *well-fed* horses, whilst in one experiment, where the animal was ill fed, and had been starved for several days, the amount of the blood corpuscles was *precisely similar* in the splenic *venous*, as in the *arterial* blood.

The conclusions that may be drawn from these

experiments are:—That the number of the blood corpuscles is *considerably diminished* in the splenic venous blood; that this diminution is constant at *every period of life;* but that it is considerably modified, according to the period of digestion at which the blood is examined; and, *more especially*, according to the *general state of nutrition* of the animal.

4. The amount of *fibrine* contained in the emerging blood of the spleen is *increased*, as compared either with *the arterial*, or the jugular *venous blood.*

TABLE III.

Table showing the amount of Fibrine contained in the Aortic, Jugular, Mesenteric, and Splenic Venous Blood.

No. of Experiment.	Hours fed Before Death.	Aortic.	Jugular.	Mesenteric.	Splenic.
1	4	4·96	...	...	5·37
2	6	...	4·32	...	6·67
3	6	...	2·36	...	3·21
4	8	...	...	3·23	2·80
5	8	...	...	7·5	8·06
6	9	1·43	2·27	...	3·89
7	10	2·53	...	...	11·53
8	10	...	5·6	...	10·88
9	16	1·79	...	...	4·31
10	48	·78	6·23	...	10·3
11	48	2·1	...	...	2·5

In six experiments on *arterial* blood the average amount of fibrine contained in 1000 parts of blood was 2·26 grains; in five experiments on the blood of

the jugular vein, the amount was 4·4 grains per 1000; whilst in twelve experiments on the splenic venous blood, the average amount was 6·4 grains per 1000, being just *double* the amount of that found in arterial blood, and *one-third more* than in the jugular venous blood. In one of the two experiments, in which the *mesenteric* venous blood was compared with the splenic, there was *rather more* fibrine than in the splenic blood; but this is the *only instance* in which the splenic blood contained *less* fibrine. Now, although these experiments distinctly prove the above-mentioned conclusion of the *increase* of fibrine in the splenic venous blood *at all periods of life*, and under *all circumstances*, it is exceedingly difficult to trace out the causes that modify its amount; its increase in one case, its diminution in another. Its variation has no relation, as far as the above experiments show, to the varying periods of digestion. Its amount appears, however, to bear some relation to the amount of blood corpuscles in the blood, the greatest quantity existing where there is the greatest diminution of the blood corpuscles, the smallest amount where there is no diminution. I have also observed that the blood of *ill-fed* or *starved* horses always affords a *very considerable amount*, as compared with the blood of well-fed animals.

Fibrine, as is well-known, contains a certain quantity of fat. In *one* experiment, in which the amount was determined in the fibrine from the arterial, jugular, and splenic blood of the same animal, the amount obtained from each was the following:

Amount of Fat contained in the Fibrine from 1000 *parts of Blood.*

	Arterial Blood.	Jugular V.	Splenic V.
Fibrine	1·42	2·25	3·78
Fat of fibrine	·01	·02	·11
Fat and fibrine	1·43	2·27	3·89

5. The amount of *albumen* contained in the splenic venous blood is greater than in arterial, jugular, or mesenteric venous blood. (See Table II.)

In five experiments on arterial blood, the average amount of albumen contained in 1000 parts of blood was 37·2 grains; the greatest amount was 45·7 per 1000, the least 22·0.

In four experiments on the jugular venous blood, the average amount per 1000 was 54·0 grains, and very little fluctuation in the quantity of albumen was observed in any of these experiments, the greatest amount being 56·40 grains per 1000, the least being 53·0 grains.

In ten experiments on the splenic venous blood, the average amount was 60·0 grains per 1000, being a much larger quantity than is found in the arterial blood entering the organ, and *more* than in ordinary venous blood. Now, although the average amount of albumen is *not very much* greater than in ordinary venous blood, very considerable fluctuations are observed in its amount, under certain circumstances; the largest quantity noted in 1000 parts was 83·30 grains, the smallest quantity 35·3 grains.

The only fact that can, I think, be deduced from

these experiments is, that the emerging venous blood of the spleen contains much *more albumen* than either arterial or jugular blood, and that the amount is subject to *very considerable fluctuations*, whilst, on the contrary, *a uniformity* is observed in *all*, excepting one experiment, as regards the amount of albumen in the other kinds of blood. In the next place, I endeavoured to ascertain *the causes* that *gave rise* to these considerable fluctuations. They appear (as the previous table will show) to have some relation *directly* with the process of digestion, but partly also with the diminution of the blood corpuscles, and partly with the condition of the animal, as regards its nutrition.

The greatest amounts of albumen appear to occur in those cases where there is a great diminution of blood corpuscles, excepting during the *latest stages* of the digestive process, where, in well-fed animals, the *greatest* diminution of the blood corpuscles is *not* accompanied by an increase in the amount of albumen.

The smallest amount of albumen exists where no diminution of the blood corpuscles is observed. (See experiment 9, Table II.)

In ill-fed and starved horses the amount of albumen contained in the splenic venous blood is much the same in quantity as that which enters the gland. (See experiment 9, Table II.)

In well-fed horses the amount of albumen is very inconsiderable during *the final completion* of the digestive process, whilst before digestion, and during its *early* stages, it is increased in quantity.

6. The amount or quality of the *fat* contained in

the splenic venous blood presents no peculiarity. In one experiment the amount was determined in the arterial, jugular, and splenic venous blood of the same horse, and gave the following results, in 1000 parts:

	Arterial Blood.	Jugular.	Splenic.
Fat in Fibrine . .	·01	·02	·11
Fat in Defib. Blood	1·91 . . .	2·60 . . .	1·23
Total amount of fat	1·92 per 1000	2·62 per 1000	1·34 per 1000

7. The serum of the splenic venous blood presented the following interesting peculiarity. In each case, the residue left, on evaporation, was of a *reddish-brown tinge*, and this colour was seen in the various substances extracted from the serum, (and even in the ash of the albumen,) after their separation from each other; whilst, on the contrary, the residue left, on evaporation, of the serum of the *aortic and jugular* blood was of a *straw* colour, in each case. In the accompanying table may be observed the results obtained from the analyses of the serum of the *aortic*, *jugular*, *and splenic blood* in *three* cases. The specific gravity of the serum, the amount of water and solid matters, the quantity and composition of each of the solid components, the amount of fatty matters, and the relative quantity and composition of the ash was in each experiment accurately examined and determined, but no peculiarity could be observed in the serum of the splenic venous blood, as compared either with the arterial or jugular blood, excepting the very remarkable fact above mentioned; a fact, the con-

Table IV.

Analyses of the Serum of the Aortic, Jugular and Splenic Venous Blood.

	I. Aortic.	II. Jugular.	III. Splenic.	IV. Aortic.	V. Jugular.	VI. Splenic.	VII. Aortic.	VIII. Jugular.	IX. Splenic.	*Peculiarities* of the *Serum of Splenic* Venous Blood.
Water	909·60	913·63	906·76	901·51	903·10	905·58	904·99	911·40	909·40	*In each case* the residue left on evaporation was of a *reddish brown* tinge, and this colour was seen in the various substances extracted from the serum (and even in the *ash* of the albumen) after their separation from each other.
Solids	90·40	86·37	93·24	98·49	96·90	94·42	95·01	88·60	90·60	
	1000·00	1000·00	1000·00	1000·00	1000·00	1000·00	1000·00	1000·00	1000·00	
Solid Matter consisting of	90·40	86·37	93·24	98·49	96·90	94·42	95·01	88·60	90·60	
Albumen	78·84	74·88	79·68	87·76	79·59	81·52	84·00	79·57	78·76	
Albuminate of Soda — Matters soluble in water	8·40	8·54	5·31	7·80	15·76	10·33	7·54	6·18	8·39	
Osmazome — Matters soluble in alcohol	2·86	1·96	6·51	2·69	1·06	1·60	3·11	2·63	2·72	
Fat — Oily fat	·30	·41	·72	·24	·49	·97	·36	·22	·73	
Fat — Crystalline fat		·58	1·02							
	90·40	86·37	93·24	98·49	96·90	94·42	95·01	88·60	90·60	
Ash consisting of										The residue left on evaporation of the serum of the *aortic* and *jugular* blood was of a *straw colour* in *all* cases.
Ash of albumen *soluble* in water	1·38	·329	·385	2·12	1·30	·92	1·20	1·29	·98	
Ash of albumen *insoluble* in water		·536	·471	·85						
Ash of Albuminate of Soda. — Ash of *matters soluble in water—Chloride of sodium principally*	4·85	5·123	3·970	4·79	6·13	6·17	5.11	4·96	5·09	
Ash of Osmazome — Ash of matters soluble *in alcohol—alkaline carbonates, phosphates, and iron*	1·24	·863	3·000	1·10	·48	·66	1·67	·58	·87	
Total amount of Ash	7·47	6·851	7·826	8·86	7·91	7·75	7·98	6·83	6·94	

For Specific Gravity, see next page.

Specific Gravity of the Serum.

Aortic.	Jugular.	Splenic.
1032·4	1028·8	1031·32
1032·8	1033·2	1033·00
1032·4	1031·4	1032·42

stancy of the occurrence of which is extremely significant.[1]

It has been lately asserted by Professor Lehmann, that the serum of the splenic venous blood presents the singular peculiarity of depositing, on the addition to it of twenty times its bulk of water, a greyish-white flocculent mass, which he calls a neutral albuminate of soda. In all the experiments (four) which have been performed, in order to determine the accuracy of this fact, such a deposit was observed in all cases, but not in the serum of the splenic venous blood alone; for in the serum of arterial or jugular blood, *a similar deposit, and much greater in quantity*, was always observed. I do not think that the above-mentioned fact, noticed by Lehmann, can be looked upon as in any way peculiar to the serum of the venous blood of the spleen.

TABLE V.

Analyses of the Ash of Aortic, Jugular, and Splenic Venous Blood.

Amount of Ash yielded by 10,000 *grains of Blood.*

	Aortic.	Jugular.	Splenic.
Soluble	62·40	66·23	65·73
Insoluble	11·60	8·77	9·67
	74·00	75·00	75·40

[1] A reference to the already detailed microscopic examination of the blood indicating the presence of coloured pigment granules, is without doubt the explanation of the above-mentioned peculiarities.

Relations of Ash to Solid Matters.

	Grs.		Grs.
Aortic .	100	. .	3·01 ash
Jugular .	100	. .	3·90 do.
Splenic .	100	. .	3·68 do.

Table VI.

Composition of 100 Parts of the Ash, deducting the Alkaline Chlorides, Iron and Sulphuric Acid.

	Aortic.	Jugular.	Splenic.
Phosphoric Acid	25·80	24·84	26·75
Alkalies	64·34	62·40	61·84
Alkaline Earths	5·23	6·40	5·70
Carbonic Acid	4·63	6·36	5·71
	100·00	100·00	100·00

Composition of the Ashes, calculating the Sodium as Chloride, and the Potash as Triphosphate.

	Aortic.	Jugular.	Splenic.
Chloride of Sodium	39·54	53·65	42·83
" of Potassium	2·01	...	7·72
Carbonate of Potash	6·05	2·46	7·50
" of Soda	...	3·24	...
Sulphate of Potash	5·69	7·52	5·07
Triphosphate of Potash	30·64	21·19	23·63
Oxide of Iron, with a little Phosphate .	11·89	7·05	8·84
Phosphates of Lime and Magnesia . .	3·50	3·95	4·17
Silica and loss	·68	·94	·24
	100·00	100·00	100·00

Table VII.

Composition of the Entire Ash yielded by 10,000 grains of Blood.

	Aortic.	Jugular.	Splenic.
Chlorine	18·48	24·43	22·30
Sodium	11·50	15·81	12·54
Potassium	·80	...	3·14
Soda	...	1·46	...
Potash	20·60	14·82	17·40
Lime	·97	1·10	1·20
Magnesia	·73	·55	·47
Oxide of iron	8·80	5·29	6·67
Carbonic acid	1·43	1·59	1·66
Sulphuric acid	1·94	2·59	1·76
Phosphoric acid	8·39	6·67	7·43
Silica and loss	·36	·69	·83
	74·00	75·00	75·40
COMPOSITION OF 100 PARTS OF EACH ASH.			
Chlorine	24·93	32·57	29·56
Sodium	15·54	21·08	16·83
Potassium	1·08	...	4·16
Soda	...	1·90	...
Potash	27·83	19·76	23·07
Lime	1·31	1·46	1·59
Magnesia	·99	·73	·62
Oxide of iron	11·89	7·05	8·84
Carbonic acid	1·93	2·12	2·20
Sulphuric acid	2·62	3·46	2·33
Phosphoric acid	11·20	8·89	9·96
Silica and loss	·68	·98	·84
	100·00	100·00	100.00

8. *On the Analysis of the Salts of the Splenic Venous Blood.*

The analyses of the *inorganic* constituents of the venous blood of the spleen (excepting the iron) do not afford the same interesting peculiarities as the analysis of the organic compounds, either as regards their quantity or their composition; and these results, though negative, are highly important, as they clearly prove that the spleen neither forms in itself, nor modifies from the entering blood, any of its *inorganic* compounds, in the form of a particular excretion, or at least to such an amount as to warrant our concluding them as in any way peculiar to the spleen.

In these analyses have been determined, 1st. The amount of ash yielded by a *certain amount of blood.* 2nd. The relation between the ash and the *solid matters* of the blood. 3rd. The relative proportions of the soluble and insoluble salts. And, 4th. The quantitative composition of each.

Similar analyses have also been made on the arterial and venous blood (jugular) of the same animal, with which it has been compared. It may easily be imagined that the amount of blood obtainable from the splenic veins of a single horse would be utterly insufficient to form *an accurate quantitative analysis* of the *ash.* Under these circumstances, the blood obtained *from twelve healthy horses* was used for these experiments, the *same* amount being obtained from the carotid and jugular vein as was in *each* case found in the veins of the spleen.

1st. With regard to the amount of ash yielded by

a certain amount of blood, 10,000 of arterial blood gave 74 grains of ash. The same amount of jugular venous blood gave 75 grains, whilst the same amount of blood from the splenic veins gave 75·40 grains.

It is affirmed by some chemists, that venous blood contains a rather larger amount of salts than arterial blood; and such was found in these experiments. The slight increase in their amount contained in the venous blood of the spleen over the jugular blood, cannot, however, I think, be looked upon as anything important or peculiar.

It immediately suggested itself to me, however, that although the amount of salts contained in a *certain quantity* of blood was not increased, still, that the amount of salts might be increased or decreased according to the amount of *solid matter* in the blood; this, however, was not observed to be the case to any material extent; for 100 grains of the solid matters of arterial blood gave 3·01 grains of ash. The same amount of solid matters of the jugular blood gave 3·90. Whilst 100 grains of the solid matters of the splenic blood gave 3·68.

In like manner, also, the determination of the relative proportions of the soluble and the insoluble salts led to no important results excepting the larger amount of insoluble salts in the *arterial blood* from the larger amount of *iron* it contained (See Table No. V.)

Lastly. The *quantitative composition* of the ash of the splenic venous blood, as compared either with the

arterial or jugular blood, as seen in the accompanying Tables, presents no such marked difference as to warrant our concluding those slight differences to *be in any way peculiar* to the spleen.

TABLE VIII.

Analyses of the Ash of the Crassamenta (deprived of Serum) of the Aorta, Jugular, and Splenic Venous Blood.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	A.	J.	S.	A.	J.	S.	A.	J.	S.
Ash of Blood in 1000 parts (*Crassamentum*)	6·34	7·3	8·11	6·39	6·2	9·00	6·87	...	8·15
Soluble	3·55	...	6·15	4·72	4·6	6·02	5·60	...	6·29
Insoluble	2·79	...	1·96	1·67	1·6	2·98	1·27	...	1·86
Iron in Insoluble Salts . . .	·41	·25	1·14	1·23	·8	1·31	1·05	...	1·74

9. The amount of *Iron* contained in the crassamentum of the emerging blood of the spleen (Table VIII.) appears, as the results of our experiments, to be increased very considerably as compared either with the arterial or jugular venous blood, as is seen in the preceding Table of experiments. And this is a highly remarkable and important fact, in connection with the *diminution* of the *number* of the red corpuscles in the

same blood. A similar result was observed by Dr. Funke in his analyses of the crassamentum.

In conclusion, the following propositions will serve to show the chief peculiarities that have been observed in the examination of the blood.

1st. The *quantity* contained in the veins of the spleen is subject throughout life to *very considerable* variation, dependent upon numerous and varied causes. These are, 1st., the period of the ingestion of food, and its subsequent conversion into blood. 2nd, the condition of the animal as regards its *nutrition*. It has been seen that, in healthy animals, the varying periods of the digestive process modify very considerably the amount of blood contained in the spleen; that the largest amount contained in the organ is, in the majority of cases, found there at the period when the ingested material has become converted into blood; the smallest amount after the digestive process has been *completed a much longer period*, when it may be assumed that the new material introduced into the circulation has been partially expended in the nutrition of the body, secretion and excretion. It has also been seen that the *condition of the animal* as regards its *nutrition*, *modifies* very considerably the amount of blood contained in the organ, although examined at the *same* periods of the digestive process, *ill-fed* or *starved* animals having, in all cases, a *very considerable diminution* in the amount of blood in the organ.

These observations appear to be highly important, more particularly in confirmation of the experiments and observations of Stukely, Lieutand, Moreschi, and

Hodgkin, all of whom had observed the extreme *variation* in the size of the organ and the *amount* of blood contained in it, but explained the causes of that variation differently. Mr. Dobson appears to have the merit of first demonstrating in an accurate manner that this variation depends upon the state of repletion of the system, the organ increasing considerably some few hours after each fresh ingestion of food, and gradually becoming smaller, as the circulation regains its normal standard, from the excess of material being used in the nutritive processes. The above-mentioned experiments not only most clearly bear out those conclusions, but they take us, I think, one step further, they show that the extent of repletion of the organ is varied according to the nutrition of the animal. They show us, in fact, that it has a still more delicate barometric influence (if I may use that expression) upon the state of the vascular system and the blood, than merely containing the 'additional quantity which the vascular system has received by the nutritive process;' for that the quantity is modified according to the state of nutrition of the animal, even although examined at the same periods after the digestive process. The experiments also in which an additional amount of blood was introduced into the vascular system, both in the portal and general venous system, lead to a similar conclusion; whilst the introduction of fluids, and their absorption into the bloodvessels, by increasing the volume of the circulation, are attended with exactly similar results. This reservoir function is nowhere more perfectly

illustrated than during a temporary obstruction of the blood, whether caused by impeded respiration, or where long continued disease of the heart or liver is accompanied by an obstruction to the course of the blood, in each and all of these cases the spleen becomes preternaturally distended from the large amount of blood that it contains.

With regard to the *quality* of the blood, the following are the most important peculiarities that have been demonstrated: a very *considerable diminution* of the blood corpuscles; *increase* of the *iron*, *albumen*, and *fibrine;* and, lastly, the deep *reddish brown colour* of the *serum*.

The *diminution* of the amount of the red blood corpuscles, from the constancy of its occurrence, is one of the most important peculiarities of the splenic venous blood. This diminution is observed at all periods of life, but presents very considerable variations, according to the different periods of digestion, the greatest amount of blood corpuscles being observed where digestion is either *not going on at all*, or only during the *early* stages of that process, the *smallest* amount when digestion is finally completed, and the new material has become converted into blood. The quantity of the blood corpuscles also varies very considerably, according to the nutritive condition of the animal, as large an amount being contained in the venous blood of ill-fed or starved horses as is found in the entering arterial blood; whilst, on the contrary, in well-fed horses a much smaller amount is observed.

The *increase* in the amount of iron contained in the

splenic venous blood is an interesting fact in connection with the *diminution* of the blood corpuscles, although that increase presents considerable variation.

Although the amount of albumen contained in the splenic venous blood presents, on the average, an *increase*, as compared with arterial, or other venous blood, the quantity presents very considerable variation at *certain* periods, and this variation is coincident with the varying amount of blood corpuscles in the blood, but is modified, also, by the digestive process, and according to the nutrition of the animal. The greatest amount of albumen occurs where there is a *great diminution* of the blood corpuscles, excepting in well-fed animals, when digestion is finally completed; and when the *greatest* diminution of blood corpuscles occurs, *then* the amount of albumen is *diminished*. The smallest amount of albumen exists where there is *no* diminution of the blood corpuscles. With regard to the modifications in the amount of albumen, as caused by digestion, it has been seen that during the final completion of that process, the amount of albumen is very small, whilst the contrary is observed during the early stages of that process. Finally, in ill-fed horses the quantity of albumen contained in the blood is *the same* as that which enters the gland.

The increase in the amount of fibrine appears to be constant and invariable, and occurs at all periods of life, but presents very considerable variations that are seen to depend either upon the nutrition of the animal, or to be coincident with a greater or less amount of blood corpuscles in the blood; the blood of

ill-fed horses always affording a *very considerable* amount as compared with the blood of *well-fed* animals. In these cases, also, where a very considerable diminution of the blood corpuscles occurs, a *great increase* in the amount of fibrine is observed, as compared with those cases where there is either no diminution or only a very partial one.

Lastly, a highly important peculiarity is the deep reddish brown colour of the residue of the serum. This colour occurs in all cases, and appears to depend upon the large amount of free hæmatin contained in solution in this constituent of the blood. The explanation of each of these peculiarities of the blood will be mentioned in considering the physiology of the organ.

Table IX.

Table showing the average results of 111 *Analyses of Aortic, Jugular, and Splenic Venous Blood (Horses.)*

Aortic.			Jugular.			Splenic.		
Clot 159·5 containing Ash 1·04	Fibrine	2·26	Clot 141·0 containing Ash ·86	Fibrine	4·15	Clot 95·12 containing Ash ·71	Fibrine	6·32
	Fat in do.	·04		Fat in do.	·05		Fat in do.	·22
	Globules { Hæmatin and Albuminous matters }	157·20		Globules { Hæmatin and Albuminous matters }	136·80		Globules { Hæmatin and Albuminous matters }	88·58
Serum 840·5 Sp. gr. 1032·5	Water	789·14	Serum 859 Sp. gr. 1031·14	Water	793·42	Serum 904·88 Sp. gr. 1032·24	Water	829·81
	Albumen	42·00		Albumen	54·40		Albumen	63·00
	Fatty matters	...		Fatty matters	...		Fatty matters	...
	Oily / Crystalline	·30		Oily ·35 / Crystalline ·49	·84		Oily ·64 / Crystalline ·92	1·56
	Extractive matters, soluble in alcohol, containing of alkaline carbonates and phosphates, with a little iron, ·84 grs.	2·42		Extractive matters, soluble in alcohol, containing of alkaline carbonates and phosphates, with a little iron, ·54 grs.	1·61		Extractive matters, soluble in alcohol, containing of alkaline carbonates and phosphates, with a little iron, 1·36 grs.	3·27
	Extractive matters, soluble in water, containing of ash, principally chloride of sodium, 4·10 grs.	6·64		Extractive matters, soluble in water, containing of ash, principally chloride of sodium, 4·6 grs.	8·73		Extractive matters, soluble in water, containing of ash, principally chloride of sodium, 4·59 grs.	7·24
		1000·00			1000·00			1000·00

THE SPLEEN PULP

Is the main element of the spleen, and that in which the Malpighian corpuscles are imbedded; it is a soft reddish substance which is lodged in the interstices formed by the interlacing of the trabeculæ. Its consistence in health is most usually soft and tenacious. Its colour varies; instead of presenting its natural brownish red tinge, it may be light red, or of a dark black red, or of a greyish colour, and this variation depends on certain changes which occur in some of the elements of the organ under certain circumstances.

The elements of the pulp are of three kinds.

1st. Small fibrous microscopic partitions.

2nd. Capillary vessels.

3rd. Parenchyma cells and blood globules.

With regard to the two former, I have sufficiently described them under their respective heads. The latter, which form the essential part of the pulp, I shall now proceed to describe, considering, in the first place, the microscopic structure, and chemical composition of the colourless elements of the pulp; and, secondly, the structure and composition of the coloured elements.

1. *The colourless elements of the pulp.*

The elements composing the parenchyma of the spleen are—

1st. A considerable quantity of exceedingly fine

granular matter, the *molecules* of which are very minute, irregular in form, and exhibit a molecular movement. These are in great part dissolved by the action of sulphuric æther, and entirely dissolved by liquor potassæ.

2nd. *Nuclei;* these are very numerous, about the size of the red blood corpuscles, and form a very considerable portion of the spleen pulp. They are either completely circular, or of a slightly irregular circular form flattened, or in some cases globular; their external margin is very dark, containing a very distinct nucleolus, the remaining portion of its structure being apparently homogeneous or dotted. In some cases their form is somewhat oblong, and instead of a nucleolus, they contain from two to four small irregular dark granules, or two nucleoli. In size they vary from the 2500th to the 5000th of an inch. Other nuclei exist having an average diameter of the 5000th part of an inch, either of a circular or of an irregular circular form, differing from the nuclei above mentioned, in their somewhat smaller size, their less dark outline, their homogeneous texture, and the absence either of nucleoli or granules in their interior—around some of these an exceedingly faint delicate membrane can be observed.

3rd. Nuclei (the same as above) around which an irregular circumscribed mass of delicate granules may be observed. These also form a very considerable portion of the spleen pulp. Occasionally these granules are arranged in a circular form around the nucleus, the margins of which in some cases present a clear

sharp line indicative of the incipient formation of the cell wall. In these the nucleus retains the same characters as those described above, or is slightly enlarged, and is more dotted and granular. In some the nucleus presents its normal size, its clear distinct dark outline, and its equally clear nucleolus or granules, whilst in others the nucleus has become more irregular in form, and instead of the clear outline it presents an indented edge, rarely it becomes paler and more indistinct, whilst, lastly, in some the nucleus is observed to have become broken up into numerous granules, which either fill up the cavity of the cell formed around them, or assist in forming the blastemal mass which surrounds the nucleus, these small granules in some cases presenting a degree of refraction which gives them the appearance of small fat globules—and in these no trace is visible of the existence of a nucleus as separate from the granular matter which previously surrounded it.

4th. Nucleated vesicles. Perfectly formed nucleated vesicles do not exist in the parenchyma of the spleen in very considerable quantity. They are of a circular form, the outer margin clear, delicate, and transparent, whilst on the wall of the vesicle may be seen a large, and, in some cases, a distinct nucleus, with its dark outer line, containing a small nucleolus, whilst in the cavity of the cell may be observed a few granules, or the cavity may be distended with the same. Their size varies from the 2500th to the 1000th of an inch. A few, which are of very considerable size, present a nucleus upon their wall, rendered in-

distinct from the very large quantity of delicate granules which completely fill up and distend the cavity of the cell; they sometimes contain two nuclei.

5th. Vesicles of a spherical or oblong form, about the 2500th part of an inch in diameter, pale, delicate, the external outline presenting a fine dark margin, and their cavity containing a few delicate granules. They do not form a very considerable portion of the spleen pulp, and in some cases cannot even be detected.

The whole of the above-mentioned elementary structures form the *colourless* elements of the pulp, and previous to our investigation of the *coloured* elements, it will, I think, be important that I should consider the laws which regulate their development, growth, and decay, and their chemical composition, as far as the application of re-agents will determine. The above-mentioned structures are of very considerable quantity and form, probably one-half or two-thirds of the whole substance of the pulp. Collected into heaps and masses of varying size, they completely fill up the interspaces formed by the partitions of the spleen, and lie also in close contact with the Malpighian corpuscles, and the walls of the capillary vessels, so as to be readily acted upon by the nutrient plasma which permeates them. Now, although the above description is intended as an illustration of their structure in *man*, the same will equally apply to the mammalia, for as far as I have been able to ascertain, they do not present any essential differences to what I have above-mentioned.

The above-mentioned *elements* of the pulp do not in all cases present themselves in *equal quantity*. Occasionally the nuclear structures predominate; at other times, again, a much larger quantity of nuclei with granular matter around them, or even nucleated vesicles make their appearance, whilst rarely the granular blastema itself forms the most important element. These facts can but lead to the same conclusions that I arrived at in my investigations of the development of this tissue, namely, that a continuous process of cell development, of cell growth and decay, takes place in the pulp of the spleen, during which nuclei are formed, around which a blastema, or, in other cases, a cell growth is produced, after which the nuclei disappear, and the cell membrane and its contents become broken up and vanish.

Not only do these elements themselves vary as to their peculiar structural difference at certain periods, but what is of infinitely more importance, is their *very extreme variation in amount* under certain conditions.

Let me now attempt to describe the law which *regulates* these *quantitative differences.*

It may be stated as a result of very numerous experiments made especially on the rabbit and rat, that the differences in the amount of these elements vary according to the period of the digestive act, and *more especially* according to the condition of the animal, as regards its *nutrition.* It has been (as far as I have been able to ascertain) *impossible* to determine at *what periods* each *separate element* exists in *greatest*

number, but I think I may confidently state that the parenchyma cells of the pulp taken together exist in *by far larger quantity*, and form a very *considerable part* of the entire bulk of the spleen, in all animals in which the nutrition of their bodies is in a most perfect condition, and more particularly in those in which the addition of new material *exceeds* that required by the waste of the body. On the contrary, I have found that the parenchyma cells *not only diminish*, but they do not *actually exist at all* in those animals in which new material has not been supplied in such quantity as was required for the waste of the body, in fact where starvation had been produced. These serve to represent the extremes of quantity, every trifling gradation of which is varied by the condition of the body generally, as far as its nutrition is concerned.

Lastly, I will consider the *composition* of these elements, as far as we are able to ascertain it by the action of chemical re-agents upon them.

On the addition of *liquor potassæ* to a portion of the pulp parenchyma it becomes *almost* entirely dissolved, and there remains a transparent viscid glutinous substance exactly similar to the white of egg, and a highly florid colouring matter, partly the red colouring matter of the blood, and partly the coloured corpuscles. These latter consist of coloured granules and masses, both of which are unacted upon by this agent. The former are either scattered indiscriminately about, or are collected into small heaps of a circular or irregular form. A few blood globules

may also be observed unacted upon. There remains in solution a fine granular amorphous mass. The addition of acetic acid to this transparent viscid mass renders it *opaque*, precipitating a flocculent and greyish-white mass; this substance to the microscope being of a finely dark granular amorphous texture, the coloured particles remaining of their natural appearance and texture.

Liquor Ammoniæ also almost entirely dissolves it, and forms a reddish, moderately transparent, viscid, glutinous substance, which, under the microscope, is seen to be composed of a finely granular, transparent, amorphous matter, the smaller and the larger coloured particles, as well as some angular apparently crystalline particles, not being dissolved. The addition of acetic acid converts this *transparent* viscid mass into an opaque greyish-white gelatinous substance, which consists of a dark granular *fibrillated* amorphous substance, the coloured masses not being acted on.

Alcohol renders the nuclei darker, and their margins more corrugated, the granules in their interior remaining the same, the coloured particles are *not* dissolved.

Sulphuric Æther. By the action of this re-agent the granular blastema surrounding the nuclei is in *part* dissolved away, the margins of the nuclei appear darker, and somewhat corrugated, the granules in their interior being unaltered, the coloured particles are undissolved.

The changes produced by the application of these re-agents show that the parenchyma cells of the spleen *consist entirely* of a *proteine* or *nutritive compound*, ex-

hibiting the characteristic tests of solubility in caustic alkalies, and re-precipitation by acetic acid in the form of a greyish-white gelatinous substance.

These observations would lead me to conclude that the parenchyma cells, which constitute the principal part of the pulp of the spleen, essentially consist of a *proteine*, or *nutritive compound*, that this compound is represented by an organized tissue, which goes through its stages of development, growth, and disintegration, and the amount of which is regulated by the condition of the animal as regards its nutrition, existing in *considerable quantity* in highly-fed animals, whilst, on the contrary, in starved animals not the *smallest portion* is capable of being discerned.

I may here allude to the very considerable resemblance that the colourless corpuscles of the venous blood of the spleen present to the parenchyma cells of the pulp. It has been already seen that these corpuscles exist in very considerable number in the emerging blood as compared with what enter the gland; from this circumstance it is evident that during the transit of the blood through the organ it receives an additional supply of these elements. Their extreme resemblance in size, form, and structure to the parenchyma cells of the pulp, and the relation of these elements to the intercellular spaces and primary veins, renders it very probable that they are derived directly from the pulp of the spleen during the passage of the blood through this organ.

2. *The Coloured Elements of the Pulp.*

The *coloured* elements of the spleen consist of red blood globules, and coloured corpuscles of various kinds, and it is to these that the pulp owes its peculiar colour. With regard to the latter I will consider the structure they present, the relations of these elements to the other tissues of the spleen, the laws which regulate their variation in quantity, and their chemical composition. In this way I trust that I may be able to explain the exact composition and uses of the various elements of which the pulp consists.

The various changes which take place in the spleen pulp, as regards the blood globules, are as follows:

In the first place there may be observed many *blood globules*, single, presenting their usual normal colour and appearance, some of which are collected into nummular rows, or heaps, or masses, of varying form and size, in some of which the outlines of the globules cannot be distinctly detected. The great majority of the blood discs, however, under certain circumstances and at certain periods, present themselves as undergoing various stages of disintegration, and this disintegration appears to take place in more than one manner.

First, some blood discs may be observed (and these are somewhat numerous at certain periods), that do not present their usual normal appearances; their size is generally smaller (they vary from the 5500th to the 7000th or 10,000th of an inch), their form

variable, circular, or more generally of an irregular circular or oblong form, or indented and wrinkled. Their colour is of a deep scarlet or orange red, and their outline very dark and highly refractive. These changes may be observed either in single blood discs, or almost as commonly, in small or large heaps, or masses of them collected together; and when such occur in masses they are of a deep red colour, or reddish brown, quite distinct in colour from heaps of unchanged blood discs. In other cases these single discs may be observed to become still more irregular and indented in form, of a darker red colour, and finally subdivide or break up into small, generally circular, minute, dark red, reddish-brown, or black granules; whilst the heaps of globules undergo a similar transition into granules, which either exist separately, dispersed in the substance of the pulp, or as masses of such dark red granules. Such, there is no doubt, is the most frequent method by which the blood corpuscles in the spleen are disintegrated.

Secondly. There are observed, *although rarely*, perfectly unchanged blood discs contained in a cell; these discs present their usual *normal* appearances. They are circular in form, of normal size, and of a pale red colour, presenting no indentation or wrinkling of their margins. In none of these could I ever detect a nucleus on the wall of the enclosing cell, which is exceedingly fine and delicate, transparent, and homogeneous in texture. The number of the contained discs varies from one to three. I have never observed more of this variety.

The more frequent form, however, in which the cells containing blood-discs present themselves is the following: They are large vesicles, which vary considerably in size; their average diameter is the 2500th of an inch, the largest 1600th, the larger size being the more frequent. Their form is generally spherical, sometimes oval or oblong. They consist of an external membrane, perfectly transparent, which *sometimes* contains on its wall a distinct nucleus of a circular form, with a central nucleolus, the nucleus being about the size of an ordinary blood disc. In many no nucleus can be seen. In the cavity of the vesicle may be seen from one to nine or ten somewhat altered blood discs, that is to say, blood discs of a circular or somewhat irregular circular form, of a *deep orange-red* colour, with an outer dark refractive margin, which sometimes presents a wrinkled edge; they do not present also the same distinctly flattened appearance that normal blood discs do. Others are observed in which the contents consist partly of the above described altered blood discs, one or more of them, however, presenting indented edges as if previously to their breaking up into dark reddish granules. Lastly, other vesicles may be seen containing a varying number of small granules, from four or five to twenty or thirty in number; these granules are of an irregular form, with dark refractive margins, and of a pale red, or dark red, or reddish yellow colour, or the vesicle contains a mass of colourless granules. These structures, in one or the other form, constitute one of the main elements of the pulp. But besides these,

there are interspersed throughout the whole of its substance granules of varying form and size in large quantities, and these are precisely similar to those found in the above described cells, and which consequently appear as the débris of the disintegrated blood discs. They vary in size; some are exceedingly minute fine granules, others exist as single corpuscles about the size of the blood discs, or aggregations of such, or in various sized masses; their form also varies considerably; their colour is of a deep red, or reddish yellow, or black, and their margins are dark and refractive. In some cases these corpuscles are so numerous as to form the chief constituent of the pulp, at other times, again, they exist only in sparing numbers. Occasionally a large number of *reddish crystalline* forms are found in the substance of the pulp, in the place of the above described corpuscles. They exist either as free crystals, of an acicular form, exceedingly minute in size, which, when seen separately, have a pale red colour, or of masses of such crystals aggregated together, when they present a brilliant red colour.

The above description of the changes which take place in the blood globules in the pulp of the spleen, is intended to illustrate the progressive changes which are observed to occur in them from a series of examinations. They do not, however, present the same appearances in man and all animals.

In *man*, I have in two cases only observed the existence of blood corpuscles included in cells, and then only in small numbers; and this, which is the

result of numerous examinations made under many varying conditions, would lead me to conclude that it is a condition which but very rarely occurs. I have more frequently, however, observed that the separate

FIG. 35.*

blood discs, either singly or aggregated in masses, present the changes that I have above described, becoming wrinkled and corrugated, presenting occasionally a dark indented edge, and finally breaking up

* This figure represents the elementary structures composing the pulp of the human spleen: *a a*, blood corpuscles; *b b*, dotted nuclei; *c c*, nucleated vesicles; *d d*, coloured corpuscles of hæmatin.

into a mass of small reddish, reddish yellow, or black granules.

Fig. 36.*

* The elementary structures composing the pulp of the spleen in the horse: *a a*, blood corpuscles; *b b*, blood corpuscles contained in cells; *c c*, blood corpuscles aggregated in masses; *d d*, reddish particles of hæmatin; *e e*, dotted nuclei; *f f*, nucleated vesicles. 1. The row at the top of the figure illustrates the process by which the disintegration of the blood globules is effected when not included in cells. 2. The row at the bottom of the figure illustrates the process by which the blood corpuscles are disintegrated in nucleated cells.

In the *horse*, and also in the *ass* (the former of which I have most frequently examined), the disintegration of the blood discs may be observed, I think, more perfectly and completely than in any other order of the mammalia. In both of these animals the disintegration of the blood discs is effected in both ways precisely as I have described above.

Among the *rodentia*, I have chiefly examined the rabbit and the rat. In the former, the disintegration of the blood discs is effected in cells and partly in those blood globules not included in cells. In the rat, disintegration of the blood globules, on the contrary, is *entirely effected* in blood globules *not* included in cells. In other animals, as the sheep and pig, I have never observed any disintegration of the blood discs.

It would appear, then, from these observations, that the disintegration of the blood discs takes place in a different manner in man and in the mammalia. In some cases the blood globules being, previous to their disintegration, included in nucleated cells, in others, on the contrary, their destruction is effected without such inclusion taking place, whilst, lastly, in some animals, both of these methods appear to be necessary. As regards the manner in which the same process is effected in birds, reptiles, and fish, a detailed account will be given in the comparative anatomy of the organ in each class.

Let me now consider where the above described elements are situated, where, in fact, the above-mentioned changes occur. Do they occur in the substance

of the pulp external to the blood-vessels, or in the smaller arteries and veins, or in both these situations?

FIG. 37.*

The changes above described occur chiefly in the substance of the pulp *external* to the vessels, *probably* also partly in the smaller vessels themselves. These coloured elements, which form, at certain periods, a large portion of the spleen pulp, consist of either free blood globules, or heaps of globules which are mingled with the parenchyma cells of the spleen, scattered throughout the pulp, being extravasated from the smaller capillary vessels and from the veins. In my description of the blood-vessels of the pulp, it was there seen that a very large number of the capillary vessels do

* The structures composing the pulp of the spleen in the rat; *a a*, blood corpuscles; *b b*, blood corpuscles in cells; *c c*, dotted nuclei; *d d*, nucleated vesicles.

not become *directly* connected with the veins, but that the blood itself traversed intercellular passages between the two sets of vessels. It was also seen that the veins, instead of communicating with each other by a plexiform network, as had been erroneously described, actually terminate or become continuous with numerous intercellular spaces, by which these vessels communicate with one another, that a venous plexus (excepting in the chelonia and ophidia) is incapable of being demonstrated; and the results of injection show that, if these vessels are filled beyond a certain point, their contents pass from the extreme ends of the vein into the substance of the pulp, that, in fact, extravasation occurs. Now if these facts are borne in mind, it is easy to conceive that when, under the numerous and very great variations in size that the spleen undergoes, the extremely delicate vessels of which its pulp consists are distended with blood, the delicate channels through which the blood passes are destroyed, and a greater or less quantity of blood, according to the increased or diminished amount of repletion of the organ, is extruded into the substance of the pulp. The occasional occurrence in some animals, in the blood of the spleen, of blood globules included in cells, as well as their various metamorphoses, might lead to the conclusion that, under some circumstances, the above described changes occur in the capillary vessels or in the smaller veins, either whilst the blood is traversing them, or from a stagnation and subsequent metamorphoses of the blood taking place in them. Now, although I am

unable to controvert this, I may say that in no animals have I in any case been able to detect the changes above mentioned to occur in the blood-vessels; and the fact of the *occasional* occurrence of these elements in the blood of some animals and their total non-existence in others, would rather lead me to believe that the pulp tissue is the situation where the above described changes chiefly, if not solely, occur, and that their disintegration occurs external to the blood-vessels. The occasional occurrence of the coloured elements of the spleen in the emerging blood probably depends upon the elements of the pulp obtaining ingress to these vessels.

Having considered the situation which the above described elements occupy, let me now consider how and in what manner the above-mentioned changes occur. It is exceedingly difficult, if not impossible, to demonstrate by what laws the disintegration of the blood globules are affected after their extrusion into the substance of the spleen pulp. The steps by which that process is effected have been already mentioned, as far as the separate blood globules are concerned, but with regard to those which undergo disintegration in cells, I have not mentioned their development and growth. I shall describe these changes now somewhat more in detail. It appears, from the result of numerous observations, that either a single blood globule or a mass of them may become surrounded by an exceedingly delicate cell wall, without the previous formation or existence of a nucleus, which, in fact, is not to be observed during

the whole period of the development and growth of the vesicle. More frequently, however, the blood globules have collected around them a variable quantity of granular plasma, in which the existence of a nucleus can be clearly detected in some cases. It would appear, then, that in *these cases* the formation of a nucleus precedes the development of the cell membrane.

These observations show that blood globules, either singly or in masses, become disintegrated when effused into the spleen pulp, without the necessity of their inclusion in cellular envelopes: that blood globules do become inclosed in a simple vesicle which appears formed in the plasma around them, and without the existence of a nucleus: that blood globules become inclosed in a distinct nucleated vesicle, but in these cases the formation of the nucleus precedes that of the investing membrane—a law which appears constant in the process of cell development generally.

It now becomes a point of very considerable importance to consider under what circumstances the above-mentioned changes occur; with what amount of frequency are they observed.

In order to obtain information on this point, I had recourse to a large number of experiments on the same horses used for the analyses of the blood of the spleen, and also upon rabbits and frogs.

In the spleens of eighty horses that I examined, disintegration of the blood corpuscles was observed in *all*, although the animals were placed under the most varied and opposite conditions. I observed

also, that in each case a large quantity of changed blood corpuscles were to be observed in every stage of metamorphosis. With regard to the variation in the *amount* of these elements, microscopic examination did not afford much information, as the quantity examined was necessarily even proximately too small to give a correct result. But even this information is highly important, as confirmatory of the result of the analysis of the blood of the same animals in each case. The only variation that I could observe was, that in starved or ill-fed horses a *much smaller* amount of normal blood corpuscles and blood corpuscles contained in cells were observed than in animals in the opposite conditions. Microscopic examination did not afford much information as regards the *variation in the amount* of these elements as observed at the varying periods of the *digestive process*. Repeated examination showed that they constantly occurred at every period of this process—before, during, and after, even a long period after the completion of the digestive act; and the chemical analysis of the emerging blood proved that, although under each of these conditions a diminished amount of blood corpuscles was detected, a more exact estimate was obtained of the *variation in the amount* than could possibly be derived from the examination of a small portion of the organ microscopically.

In *well-fed* rabbits, the amount of normal blood corpuscles contained in the pulp was very considerable, as compared with the *small* number observed in *ill-fed or starved* rabbits. In the former, I occasion-

ally detected the existence of blood corpuscles in cells. Some of the normal blood discs also presented a wrinkling and indentation of their margins, as if in process of disintegration, and there also existed a large number of vesicles containing variously shaped reddish yellow corpuscles. With the exception of a much *smaller amount* of these elements, and particularly of normal blood discs, the same was observed in ill-fed or starved rabbits.

In frogs and toads, also examined under every variation as regards their nutrition and digestion, I in every case detected the same changes of disintegration in the blood corpuscles that I have elsewhere described. The only difference that I could detect was considerable variation in the amount of this disintegration at varying periods, animals examined when quite recently caught exhibiting these changes in a greater degree as compared with those which had fasted for a very considerable period.

Let me, in the next place, consider the chemical composition of these coloured corpuscles, as far as the application of chemical re-agents will determine. If the changes which I have above described are correct —namely, that these corpuscles are formed by a disintegration of the red blood discs, it appears almost a legitimate conclusion that they have some relation to the colouring matter of the blood, and that in their composition they are allied to hæmatin ; and such appears to be the result of the experiments on this substance, which I shall now briefly mention.

These coloured corpuscles are *insoluble* in boiling

or cold water, alcohol, æther, and acetic acid; and so far this substance resembles hæmatoidin, which is unacted upon by the same re-agents. It is *partially soluble* in boiling dilute nitric acid, which renders the fluid of a pale yellow tinge. It is also *partially soluble* in a boiled dilute solution of potash, giving the fluid a brownish green tint, the colouring matter being precipitated on the addition of nitric acid. It is almost *entirely dissolved* by boiling liquor potassæ, the fluid becoming of a dirty greenish yellow colour, the colouring matter being precipitated on the addition of nitric acid, but without presenting any of the shades of colour noticed when bile pigment is present. It is *completely dissolved* by boiling nitric acid, rendering the fluid of a pale yellow colour, which, on the addition of liquor potassæ, becomes of a dark yellowish red colour, and, on the addition of ammonia, is again reprecipitated.

These experiments show that the colouring matter contained in the pulp of the spleen is closely allied to the colouring matter of the blood, inasmuch as the behaviour of this substance, on the application of certain tests, presents many of the characteristics, both of hæmatin, and hæmatoidin. The supposition of some physiologists of its analogy with the colouring matter of the bile, made me especially careful in the examination of this substance. The tests, however, usually adopted, distinctly showed that it did not present the least resemblance with it, the experiments being repeated in numerous instances with a similar result.

It would appear, from a careful consideration of the

above facts, that the coloured elements of the spleen, which constitute occasionally a considerable portion of the pulp, essentially consist of a substance closely allied to the colouring matter of the blood, from which it is, in fact, formed, when, under certain circumstances, blood is extruded from the blood-vessels into the substance of the pulp.

The preceding investigations have shown, that in the pulp of the spleen in many animals, and at certain periods, a varying number of normal blood globules are extruded into the substance of the pulp, and there undergo a transformation of their elements, the free blood globules becoming altered, their colouring matter forming the coloured corpuscles, or the coloured crystals found in the tissue of the pulp, whilst the same changes are observed in those blood globules which are included in cells. What is the ultimate destiny of these ? What becomes of the large quantity of coloured corpuscles and crystals contained in the pulp, and of the cellular envelopes which invest them, and which become occasionally converted into granule cells ? With regard to the coloured corpuscles, it has been already seen that the emerging blood, and even the lymphatic vessels, contain some of these granules, but they exist usually in such small numbers that it is absolutely impossible that these fluids can convey away the large quantity contained in the pulp into the circulation in a solid form ; it is more probable, however, that they finally break up and become dissolved, and so are conveyed away by the blood, giving to the serum the dark reddish brown tinge that its residue

in all cases presents. With regard to the plasma surrounding these changed corpuscles, the nucleated vesicles in which they are occasionally contained, and the colourless granule cells into which they, in some cases, become converted, it is probable that they also finally break up, and again enter the circulation, and assist in forming the increased amount of fibrine and albumen contained in the emerging blood.

Although it may be freely admitted that the changes above mentioned do take place in the spleen, it may be asked: Is this the only organ in which these changes occur; are blood globules ever found in any other organs undergoing the same transformation as has been observed in the pulp of the spleen?

In man, I have never observed any changes in the blood globules of other organs similar to those that I have noticed in the pulp of the spleen.

In none of the mammalia, also, that I have examined—namely, the horse, ass, dog, cat, rabbit, and rat—have I ever noticed the disintegration of the blood discs in any other organ.

In birds also, and reptiles, and in some fishes, the same results have been observed.

In other fishes, however—as in the bream, carp, and tench—I have frequently noticed the blood corpuscles presenting the same appearances in the kidneys and liver as I shall elsewhere describe in the spleen of these animals. They were not, however, of constant occurrence, nor did they exist in large numbers.

These observations would lead me to conclude, that the changes above mentioned observed in the blood

globules in the pulp of the spleen, are peculiar to this organ, in the higher vertebrata, and that they consequently represent a part of the function which this organ normally performs.

CHEMICAL ANALYSIS OF THE PULP IN MAN AND THE OX.

The preceding investigations on the composition of the elements of the pulp of the spleen, as determined from their behaviour with certain chemical re-agents, serve to afford a very limited knowledge of their structure, and do not add the least information regarding the composition of the fluid element of the pulp, the nature of the inorganic constituents, or the ultimate elements of which it is formed. It is this important part of my subject that I shall now proceed to examine ; and if we consider how intimately the use of the spleen is dependent upon the nature of the fluid and solid constituents which form the pulp, it must be allowed that there is no part of the present investigation that has a more important bearing than that which relates to their chemical composition, more especially in connexion with the composition of the emerging blood.

During the last few years, Scherer, in Germany, has made a long-continued series of investigations on the composition of the pulp of the spleen, the results of which he has published from time to time. In his analyses he mentions the existence of a number of entirely new compounds, as well as of uric acid in large quantities. The highly important character of these

analyses determined me to investigate, in a precisely similar manner, the exact composition of this organ, and the results of my observations have been, in many respects, so much at variance with his statements, that I have felt bound to enter into a somewhat tedious, though detailed description of the methods in which the analyses were conducted ; at the same time I shall place a brief summary of these results at the end of this description, to which a table is appended, illustrating the chemical composition of the organ, as determined from my analyses.

(*Proximate Analysis.*)

Determination of the Amount of Water and Solid Matter in the Spleen.

The amount of water and solid matter composing the trabecular network was as 1 solid to 3·39 water.

The amount of *water* and *solid matter* composing the pulp was, at *different periods of life*, as follows:

Æt.	Solid Matter.		Water.	
16 . . .	1	to	4·56	*Average*, 1 *to* 4·10
28 . . .	1	to	3·90	
35 . . .	1	to	4·73	
35 . . .	1	to	4·77	
48 . . .	1	to	3·40	
61 . . .	1	to	3·24	

The amount of water and solid matter composing the entire organ was at different periods of life as follows:

Æt.	Solid Matter.		Water.	
6 weeks . . .	1	to	3·7	*Average*, 1 *to* 3·80
33 . . .	1	to	3·87	
35 . . .	1	to	3·31	
39 . . .	1	to	4·35	

These experiments serve to show the amount of water and solid constituents of the entire substance of the spleen, the pulp tissue of the organ separately, and the trabecular network. I shall now enter into a detailed account of our Proximative Analysis, in order to determine the composition of its organic constituents.

PROXIMATE ANALYSIS OF THE SPLEEN.

In the first experiment three bullocks' spleens were sliced and well mixed with water, and the trabecular tissue and capsule being removed, the liquor was slowly heated to about 180°F., by which the greater portion of the albuminous matters were coagulated, and some of the colouring matters thrown down. It was then filtered through a linen cloth, and to the clear yellowish brown liquid, baryta water added in considerable excess; a copious precipitate fell, which was removed by filtration, and the clear liquor evaporated on a water-bath, at a temperature not exceeding 130°; as the concentration proceeded the surface of the liquor became covered with a pellicle of albuminous matter, which was skimmed off from time to time. The concentration was continued till a syrupy mass was obtained, which, on cooling, became a stiff jelly. It was set aside for a week, in order to see if any crystals of *kreatine* would make their appearance ; none, however, could be detected by a most careful microscopic examination. The same experiment was repeated with three more spleens, with a similar negative result as regards kreatine.

The *absence* of *kreatine* being thus confirmed, four

more perfectly fresh spleens were taken, and the trabecular matter being removed as before, the pulps were boiled for a quarter of an hour with distilled water, by which the albuminous and colouring matters were thrown down, whilst in the aqueous solution all the soluble parts were suspended.

We have consequently to analyse those products *insoluble* in water, and also those that are *contained in solution.*

The insoluble portion, which formed the chief component of the pulp, was of a *dark brownish colour.* On submitting a portion of this to boiling dilute spirit, to which a small quantity of sulphuric acid was added, a clear *dark red* solution was obtained, which, on cooling, deposited a quantity of greyish white flocculent precipitate, the red colouring matter remaining in solution. On evaporating this fluid the colouring matter separated in the form of thin flattened *reddish brown laminæ*, exactly like the lees of port wine. These *coloured* laminæ were soluble in dilute boiling liquor potassæ, forming a deep red solution. On the addition of hydrochloric acid, the colouring matter was precipitated of its original colour, *not* in green flakes; and on the addition of nitric acid the colouring matter was likewise precipitated, not, however, giving the varying shades of colour which bile pigment in all cases presents. These experiments show that the colouring matter separated by the spirit from the *insoluble* portion of the pulp is precisely analogous to the *hæmatin* of the blood. The *insoluble* portion which remained in the spirit solution, and which was now

freed from its peculiar colour, presented all the characters of pure *albumen*, being coagulated by boiling, being insoluble in water and alcohol, and by its solubility in caustic alkalies.

The insoluble portion of the pulp is thus shown to be composed of two organic compounds, *albumen* and *colouring* matter, allied to the *hæmatin* of the blood.

We must now examine the *soluble* portion of the spleen pulp. This, after being separated from the insoluble part by filtration through a linen cloth, was treated with baryta water until strongly alkaline; filtered from the precipitate; concentrated by evaporation; the excess of baryta removed by the addition of slight excess of sulphuric acid, filtered, and the filtrate reserved for distillation.

The precipitate occasioned by baryta water, as well as that subsequently obtained by sulphuric acid, was washed, and each dissolved separately in dilute boiling caustic potash. Dark brownish red solutions were obtained, which, after being filtered from the insoluble residues, gave, with hydrochloric acid, copious fawn-coloured precipitates. These precipitates were carefully examined under the microscope. They did not appear to have the least crystalline form, neither could any crystals be detected in the mass after it had remained for a long time in contact with hydrochloric acid.

Portions of each precipitate were treated with a drop of nitric acid on a small porcelain dish. Yellow solutions were obtained, which were cautiously evaporated. The residue obtained was *brownish yellow*,

without a shade of red or purple. The addition of a drop of ammonia did not give the re-action of murexide; and caustic potash produced an intense yellow colour, instead of a *violet tint*. These experiments were repeated a great number of times, on different preparations, but in no instance did the microscope reveal any crystalline forms, nor could any proof of the existence of uric acid be obtained by the chemical tests.

The properties of the precipitates from the alkaline solutions by hydrochloric acid, were these: They were readily soluble in caustic and carbonated alkalies, and in ammonia forming dark red solutions, from which the flocculent matter was precipitated, unaltered by the addition of a slight excess of hydrochloric acid. On the addition of muriate of ammonia to a caustic potash solution, no gelatinous precipitate was produced after standing for nearly a week, neither was there any precipitate formed by allowing a stream of carbonic acid gas to pass through the solution for a considerable time. The ammoniacal solution, on being evaporated to dryness on the water-bath, left a brown laminar shining mass, which dissolved with effervescence in dilute nitric acid; the acid solution, when evaporated to dryness on the water-bath, left a pure yellow residue, which, on the addition of a drop of caustic potash, became much darker.

The potash solution of the ammoniacal residue gave no precipitate with carbonic acid, but with hydrochloric acid the flocculent matter reappeared.

In another set of experiments with *four spleens*, the

coagulated pulp was boiled four successive times in distilled water, being squeezed in a powerful press after each boiling; and before the addition of baryta water it was filtered, by which a perfectly clear bright yellow liquid was obtained. The precipitates obtained on treating the caustic potash solutions with hydrochloric acid were, in this experiment, less coloured, and the alkaline solutions had a less red tint, but in every other respect the properties of the precipitates were the same as before, and in none could the existence of uric acid be detected.

These results differ materially from those obtained by *Scherer*. According to that distinguished physiological chemist, the precipitates, by baryta water, and subsequently by sulphuric acid, contain two organic bodies, which dissolve in dilute caustic potash, from which they are separated by hydrochloric, and also by *carbonic* acid. The precipitates obtained by the German chemist are described as being crystalline, and as yielding distinct and large yellowish-coloured crystals, after long contact with hydrochloric acid. They are moreover stated to give, with nitric acid and ammonia, the brilliant purple colour of murexide. In Scherer's experiments, a gelatinous precipitate of *urate of ammonia* was obtained on mixing the caustic potash solution of the crystalline precipitate with muriate of ammonia, and from the filtered liquid a yellowish white crystalline powder was deposited on gentle evaporation. This crystalline powder was readily soluble in ammonia, and when the ammoniacal solution was evaporated to dryness, and tested with

nitric acid, it gave a purely yellow stain. Thus far it agrees in properties with the substance obtained in the experiments described above; but on passing a current of carbonic acid through the potash solution, Scherer obtained a white crystalline powder, soluble in nitric acid, *with* disengagement of gas, but very sparingly soluble in boiling hydrochloric acid. The new substance was very sparingly soluble in cold water, and was deposited from its solution in hot water in the form of a fine powder. It was also soluble in hot alcohol. Its solution in hot nitric acid yielded white crystals on cooling. On analysis numbers were obtained, which led to the formula $C_5\ H_2\ N_2\ O$, which is xanthic oxide — 1 equivalent of oxygen, and which differs from uric acid in containing 2 equivalents of oxygen less. Scherer gives it the name of *hypoxanthine*, and states that he has found it in the human spleen at all periods of age, and likewise in the substance of the heart.

I was exceedingly anxious to confirm these interesting observations of Professor Scherer, but although I followed his method of analysis to the letter, and worked in one experiment on the spleens of twenty-five oxen, I have wholly failed in detecting either uric acid or hypoxanthine. The same experiments were performed in a precisely similar manner on the pulp of the *human spleen*, and with a similar negative result as regards the presence of uric acid and hypoxanthine.

Examination of the Aqueous Extract of Nine Bullocks' Spleens, after the Separation of the Precipitates by Baryta Water, and subsequently by Sulphuric Acid.

The concentrated liquor, amounting to about three pints, and which contained an excess of sulphuric acid, was submitted to distillation in a copper still, in which a thermometer was inserted for regulating and noting the temperature. The first two pints came over at 212° F.; it was rather milky, and slightly acid. The temperature then began to rise, the receiver was therefore changed, and all that came over between 212° and 280° was received in the second vessel; it amounted to about half a pint; it was perfectly clear and strongly acid. When the thermometer reached 280°, the character of the distillate began to alter. It now assumed a yellowish white colour. The receiver was again changed, and all that came over between 280° and 340° was collected separately. At this temperature, and between it and 380°, heavy black oily drops came over, which were collected in a fourth receiver, containing a little water; the drops fell to the bottom of the water as they passed into the receiver. The distillation was now stopped. On examining the residue, it was found almost perfectly dry, and in the form of a brownish-black porous coal.

The four distillates were examined separately.

The first (that passing over at 212°, and amounting to about two pints) was saturated with carbonate of

soda, and evaporated to dryness. The dry residue, which had a brown colour, was again distilled in a small glass retort, with slight excess of sulphuric acid. An acid liquor passed into the receiver, which was again neutralized with carbonate of soda (an excess being avoided), and evaporated to dryness. A crystalline mass was obtained, very little coloured. It was readily soluble in water. On the addition of a few drops of nitrate of silver to a portion of the solution in a test-tube, a precipitate was obtained which at first was nearly white, but on applying heat it became dark, and in a short time the bottom and sides of the tube became covered with a shining metallic deposit of reduced silver, thus proving the liquid which passed over at this temperature contained *formic* acid; but it is by no means to be inferred from this that formic acid exists ready formed in the spleen, it being well known that this acid is produced under a great variety of circumstances, from *many* organic compounds, and particularly by the action of sulphuric acid upon them.

The second distillate (that passing over between 212° and 280°) was likewise saturated with carbonate of soda, evaporated to dryness; and the residue, re-distilled with excess of sulphuric acid, a clear colourless strongly acid liquor passed into the receiver. A portion of the distillate was exactly neutralized with carbonate of soda, and on adding to the solution, in a test-tube, a drop of perchloride of iron, a deep blood-red colour was produced. Another portion was mixed with sulphuric acid and alcohol, and

heated, when the unmistakeable odour of *acetic ether* was evolved. The acid in the second distillate was, therefore, principally *acetic*, mixed, however, probably, with the acid which stands immediately below it in the series of volatile acids, viz., the metacetonic, or aceto-butyric, which agrees with acetic acid very closely in properties. This acetic acid exists in large quantities, and, unlike the formic acid, is probably preformed in the spleen pulp.

The third distillate (that passing over between 280° and 340°), which was very turbid and strongly acid, was mixed with half its volume of sulphuric ether, and well agitated. On standing, it separated into two layers, the upper of a bright yellow colour, and the lower of a paler yellow. The upper etherial solution was drawn off by a pipette. A fresh quantity of ether was then added, and the mixture again well agitated. On standing, it separated as before into two layers, the lower one being now almost colourless. The etherial solutions were mixed and distilled in a small retort, on a water-bath. A small quantity of a dark brown syrupy liquid remained, which was strongly acid, and had an acrid burning taste, and an exceedingly disagreeable smell. It was boiled with alcohol, in which it dissolved, with the exception of a small black oily globule, which, after being washed, was no longer acid; its quantity was too small to admit of any further examination being made. The alcoholic solution was evaporated to a gummy consistence. It was highly coloured, but on

treating with distilled water, a clear light yellow, strongly acid, and exceedingly acrid liquid was obtained, a black pitchy residue remaining undissolved, which, by repeated washing, was completely deprived of all acid re-action. The aqueous solution was evaporated on the water-bath. A pale yellow oily drop remained, strongly acid, and having the well marked and offensive smell which characterizes *butyric acid.*

The aqueous solution lying beneath the etherial was strongly acid: it was neutralized with carbonate of soda, concentrated by evaporation, and then distilled in a small retort with excess of sulphuric acid. The distillate was colourless, very sour and pungent; it consisted principally of acetic acid, mixed, probably, with aceto-butyric acid.

Of the fourth distillate, too small a quantity was obtained to admit of a close examination. The black oily drops were found, after standing for twenty-four hours, to be completely dissolved in the water in the receiver in which they were collected, communicating to it a dark colour, and a peculiarly disagreeable odour. On evaporating the solution, the dark oily drop reappeared. All I have to say respecting it is, that it was strongly acid, had a most disagreeable odour, resembling putrid urine, and an acrid burning taste. It probably consisted of a mixture of butyric and valerianic acids, together with some neutral oily products, which communicated to it its dark colour and peculiar smell. The results of these analyses,

which were confirmed by a second distillation of the aqueous extract of four bullocks' spleens, are precisely similar to those obtained by Scherer.

I shall now mention the methods adopted for determining the presence of lactic acid in the spleen.

The aqueous extract of three bullocks' spleens having been treated in the usual manner with baryta water, and subsequently with slight excess of sulphuric acid, was strongly concentrated by evaporation, and then mixed with four times its bulk of alcohol, allowed to stand for a day, and frequently agitated. A very considerable precipitation, consisting principally of gelatine, took place. The clear alcoholic extract was drawn off, and a second quantity of spirit added. This, after standing a day, was drawn off, and a third quantity added. The insoluble matter was now nearly colourless (it had a faint yellow tinge), and the alcohol was only faintly coloured. The spirituous solutions were mixed, and about four-fifths of the spirit distilled off. The impure residue in the retort was treated with baryta water to a strong alkaline re-action, filtered from the sulphate of baryta, and a current of carbonic acid passed through the filtrate, till the excess of baryta was removed. All the organic acids existing in the original aqueous extract were now in alcoholic solution, in the form of baryta salts. The solution was strongly concentrated on the water-bath, again treated with alcohol, and filtered. The clear solution was placed over sulphuric acid *in vacuo*. In twenty-four hours a considerable crystallization had taken place, and the

liquid had spontaneously evaporated to a syrup. This syrup was removed with a pipette, and boiled with an aqueous solution of sulphate of lime, filtered from the insoluble sulphate of baryta, and strongly concentrated. A confused crystalline mass was obtained, in which, with a strong lens, the peculiar double brushes, or delicate needle tufts, of lactate of lime could be detected. (I must here observe that I had prepared a large quantity of pure lactate of lime, by the excellent process recommended by Bensch,—*Annalen*, Feb., 1847,—in order to compare with the crystals obtained.) To endeavour, however, to get better proofs, the mixed lime salts were re-dissolved in a small quantity of water, decomposed with slight excess of sulphuric acid, evaporated to a syrup, and then agitated with a mixture of one part of alcohol and *five* parts of ether; by this means much of the colour was removed. The etherial solution was distilled, and the residue in the retort mixed with strong lime water, and boiled; then mixed with an equal volume of alcohol (thoroughly to precipitate the sulphate of lime), and filtered. Into the filtrate a current of carbonic acid was passed, and the liquid, filtered from the precipitated carbonate of lime, was again placed over sulphuric acid *in vacuo*. After two days it had become a crystalline mass, in which the same needle tufts that were observed before could again be detected.

The evidence, therefore, that I have to offer with respect to the existence of lactic acid in the pulp of the spleen, is that furnished by the crystalline double

tufts of lactate of lime *twice* observed in the crystallization from the alcoholic and etherial solutions. I can consequently entertain no doubt that lactic acid *is* a constituent of the spleen, a result confirmatory of the analysis of Scherer.

ANALYSIS OF THE INORGANIC CONSTITUENTS OF THE PULP.

A healthy human spleen, weighing 2298 *grains*, gave 23·05 *grains* of ash, of which 16·75 *grains were soluble*, 6·30 *were insoluble.*

In a second experiment, a healthy spleen, weighing 2178 *grains*, gave 21·49 *grains of ash*, of which 17·62 *were soluble*, 3·87 *insoluble.*

These amounts serve to afford a very fair criterion of the quantity of ash yielded by a certain known weight of the spleen, but in each case it was far too small to make a quantitative analysis. Under these circumstances, the spleen of the ox was selected, which, from its large size, gave a sufficient amount of ash to enable a quantitative determination of its composition to be made. In this experiment the *pulp* of the spleen of an ox, separated from the trabeculæ and larger vessels, gave 119·44 *grains.*

Ash obtained from the *Soluble* Portion of the Pulp .	83·74
Ash obtained from the *Insoluble* Portion	35·70
	119·44

Composition of the Ash of the Soluble Portion (which, when burned, was White as Snow).

Chloride of Sodium	19·51
Sulphate of Potash	3·50
Phosphate of Potash	60·73
	83·74

Composition of the Ash of the Insoluble Portion (of a Yellowish Colour).

Phosphate of Iron	Phosphoric Acid	14·40
	Peroxide of Iron	16·30
Earthy Phosphates with a little Alkaline Do.		5·00
		35·70

Composition of 100 *Parts of the Ash.*

Ash of Soluble Portion	Chloride of Sodium		16·26
	Sulphate of Potash		3·00
	Phosphate of Potash		50·50
Ash of Insoluble Portion	Phosphate of Iron	Phosphoric Acid	12·00
		Peroxide of Iron	13·58
	Earthy Phosphates and Alkaline Do.		4·66
			100·00

Composition of the Entire Ash, without calculating the various Elements together.

Chlorine	11·47
Sodium	8·04
Potash	36·73
Phosphoric Acid	40·40
Peroxide of Iron	16·30
Sulphuric Acid	1·50
Earthy Phosphates	5·00
	119·44

Table illustrating the Chemical Composition of the Pulp of the Spleen of the Ox.

The *average* amount of solid matter to water in the pulp is as 1 to 3·80.

COMPOSITION OF THE PULP.				
	Organic Compounds.		Inorganic Compounds.	
Pulp Insoluble in Water, Composed of	*Albumen* in large quantities, and rich in *Iron* . . *Colouring matter*, analogous to the *Hæmatin* of blood	*Ash* consisting of	Phosphate of Iron: Phosphoric Acid	14·4
			Phosphate of Iron: Peroxide of Iron	16·3
			Earthy Phosphates, and a little Alkaline	5·0
				35·7
Pulp Soluble in Water, Composed of	*Gelatine*, probably derived from small vessels and trabeculæ . . . . *Colouring matters*, analogous to the colouring matters of urine, and the juice of flesh . . . . *Lactic Acid* in large quantity . *Acetic Acid* in large quantity . *Formic Acid* . . *Butyric Acid* . . both doubtful: *Valerianic Acid* . . . *Metacetonic Acid* . . .	*Ash* consisting of	Chloride of Sodium	19·51
			Sulphate of Potash	3·50
			Phosphate of Potash	60·73
				83·74

For Ultimate Analysis, see next page.

Ultimate Analysis of the Spleen.

The Ultimate Analysis of the dried pulp of the spleen of the ox, taken from the average of several experiments, in 100 parts was:

Carbon	52·03
Hydrogen	7·40
Nitrogen	13·00
Oxygen and Sulphur	19·85
Ash	7·72
	100·00

Uric acid could in no single instance be detected.

No substance presenting the properties of *hypoxanthin* could be found.

The usual tests *for bile* failed in detecting the existence of any acids analogous to the *biliary acids.*

The tests for *sugar* also failed to discover the existence of this compound.

The results of these analyses serve to show that the chief component element of the spleen is an *albuminous* product, and consequently, that the chief part of the *secretion* of this gland is a *proteine*, a *nutrient compound.* It has been also seen that a very considerable quantity of *colouring matter*, analagous in all its properties to the *hæmatin* of the blood, forms one of the constituents of this gland. There appears every reason to believe that this substance is formed from the colouring matter of the blood globules, which, under certain circumstances, are observed to undergo a process of disintegration. The large

amount of *iron* which is also found in the insoluble portion of the spleen containing the above products, and which exists in *much larger* quantity than can be accounted for by the amount of blood in the organ, is also probably derived from the débris of the large quantity of disintegrated blood discs which the pulp of the spleen frequently contains.

It is highly probable that the lactic and phosphoric acids (both of which are found in considerable quantity) exist, pre-formed, in the substance of the pulp, and give to it the peculiar acid reaction which this organ usually presents. It is hazardous to offer any theory of their mode of formation.

With regard to the other acids, the formic, acetic, butyric, valerianic, and metacetonic, it is doubtful whether they are pre-formed in the substance of the spleen, or exist as educts of the process by which they are obtained, being capable of formation, probably, from any animal compound acted upon by sulphuric acid, and submitted to distillation.

THE SPLENIC CORPUSCLES

Are small semi-opaque bodies, of a gelatinous consistence, disseminated throughout the substance of the spleen, and surrounded by the spleen parenchyma, giving to the cut surface of the healthy organ a speckled greyish-white appearance.

These bodies may be observed in the *healthy organ* at all periods of life, but they are larger and more distinct in early than in adult life or in old age. In some cases, however, where the organ exhibits an apparently perfectly healthy condition, they are invisible to the naked eye; and in many cases where considerable congestion of the vessels exists, they are not to be observed. It is not improbable that it was under these circumstances, as well as from their extreme delicacy, that their existence in the human subject was repeatedly denied by many observers of the greatest eminence, or that when present they were regarded as abnormal structures. Their size is smaller than in most mammalia. In this class these bodies are universally present, and in some—as the ruminantia—they are of considerable size. They are also present in considerable number in birds. In reptiles and fishes, they are absent.

In describing the structure of these glands, I shall consider, in the first place, their general anatomy, the structure of their capsule, and of their contents, their relation with the blood-vessels, and their

chemical composition; lastly, I shall attempt to discover the laws which regulate the very extreme variations in size which they present under certain circumstances.

Their Form

Is chiefly spherical, or nearly so, the great majority approaching more or less to this form; some few present a somewhat conical or pyriform shape. Their circumference is not in all cases perfectly circular, their sides being flattened, giving to them a flattened spherical or ovoid form.

Their Size.

The size of the Malpighian corpuscles varies very considerably; and this variation is to be observed not only at the different periods of life, but also at the same period of life at different times, and under different circumstances. On what causes and under what conditions these alterations depend will be considered at a future place. In the adult human healthy subject they vary between the one-tenth and one-fourth of a line, the average size being about the one-fifth to the one-sixth.

Their Number.

Almost as much variation is to be found in the number of these bodies as in their size. If a section of the healthy gland is examined with great care, I think they will be found to be far more numerous

than is generally believed, so as to constitute a very considerable portion of the spleen. It is very difficult, however, to isolate them in sufficient numbers from a previously known weight of the organ, to be able to form a perfectly correct estimate, but in many cases they are so densely disseminated through it as to give a speckled white appearance to the mass itself; the sides of the corpuscles, in some cases, being almost closely approximated to one another, or being merely separated by a portion of the pulp parenchyma. Where they exist in these numbers, I should think they form about one-fourth to one-fifth of the whole of the pulp tissue. In other cases, however, their number is less, forming from one-sixth to the eighth part of the entire substance. Whilst, lastly, in some cases their number is so inconsiderable, that they must form but a very small proportion. Their number, as well as their size, appears to be far greater in proportion to the size of the organ in early and adult life than in old age. Upon what these variations depend will also be considered at a future place.

Their Consistence.

In the human subject they present a very delicate consistency, so much so, that it requires the greatest care in their manipulation to obtain them entire; in fact, they appear in most cases almost gelatinous, and are ruptured on the application of the very slightest force. Under other circumstances, their contents present a more solid texture.

Their Colour.

The colour of these bodies is usually semi-opaque and whitish, in some cases almost transparent; so much so, that they are overlooked, unless examined for with very great care. I have never observed them of a reddish tinge.

Their Situation and Connexions.

The Malpighian bodies are imbedded in and completely surrounded by the spleen pulp, excepting at the point where they are attached to the sheaths of the vessels. When this substance has been carefully removed from them, they are found to be connected with the sheaths of the smaller arteries and their branches in a somewhat varied manner, being suspended on them, and presenting a resemblance to the buds of the moss-rose, or the berries on a bunch of grapes (Fig. 38). They are connected to the arteries in one of three ways:—1st, The most numerous are placed either in or at some point of the angle of bifurcation of the arteries, generally within their angle of bifurcation, so that the large ramifications inclose them and surround their sides; others are connected to the arteries by small peduncles, but these are far less numerous than the former. These peduncles may be of two kinds, (1st) very small arterial twigs of a diameter varying from the 150th to the 250th of an inch, surrounded by their sheath of fibrous tissue; or, 2ndly, small prolongations of fibrous tissue from the

FIG. 38.*

sheaths of the vessels at the extremity of which the corpuscle is attached; 3rdly, Some of these bodies, but these are exceedingly few in number, lie on the wall of the arteries, both on the smaller, as well as,

* This figure is intended to show the form of the splenic corpuscles, their situation in connection with the angle of bifurcation of the small arteries, and these vessels ramifying on their surfaces. From the sheep.

though more rarely on the larger branches, being devoid of any peduncle, and not being placed at the angle of bifurcation of the vessels themselves.

Structure of the Splenic Corpuscles.

If these bodies are examined in a healthy state they generally present a swollen and turgid appearance, and if cut or punctured collapse, whilst at the same time a fluid flows from them; and a similar result is obtained if slight compression is used. These facts prove that these bodies are composed—1st, Of an external capsule; 2ndly, Of fluid contents.

STRUCTURE OF THE CAPSULES OF THE SPLENIC CORPUSCLES.

The capsule of the splenic corpuscles consists of an external membrane, which forms a complete sac, containing a cavity in which the contents of the corpuscles are situated.

This membrane may be easily demonstrated by pressing out the contents of the corpuscle, and acting upon them by diluted liq. potassæ, by which the contents are entirely dissolved, but the investing capsule remains unaffected.

The membrane is exceedingly delicate, amorphous, colourless, and perfectly transparent; it presents a very distinct and clear outer margin, which, however, is sometimes interrupted by depressions, which give to it a somewhat lobed appearance, and generally presents a double contour. It consists of an

Fig. 39*

exceedingly dense plexus of fine pale fibres, which interlace with one another in all directions, some of these being disposed in a longitudinal, others in a transverse, arched, or oblique direction; the meshes formed by the interlacing of these delicate fibres are closed up by an exceedingly fine, delicately granular, and minutely striated membrane, not unlike the basement membrane of the glands. (Fig. 39.) This membrane in man is homogeneous, and presents a number of small, short, pale, oval-shaped markings, not unlike flattened elongated nuclei in its substance.

The fibres which compose this net appear to be of

* A portion of one of the splenic corpuscles acted upon by diluted liquor potassæ, to show the structure of the external capsule.

two kinds—1st, pale white homogeneous fibres, and 2nd, the curling elastic ones, the former of which appear to exist in by far the largest proportion, and form the chief part of its structure. The largest of these fibres measure the 10,000th part of an inch in diameter. They are pale, apparently flattened, and homogeneous or faintly granular in texture; they subdivide and unite with branches from neighbouring fibres. They are not, however, equally disposed over the whole of the capsule, for in some parts they are aggregated into bundles, which traverse its surface generally in its long axis.

The curling elastic fibres are much less numerous in quantity; they present their peculiar tortuous and curly course, being disseminated somewhat sparingly through the substance of the membrane. In the human subject the pale white fibres are somewhat less distinct and smaller than in the mammalia. A few of the fibres present a small oval-shaped nucleus. No spindle-shaped or muscular fibres could be observed entering into the formation of its structure.

MODE OF FORMATION OF THE CAPSULE OF THE SPLENIC CORPUSCLES.

The external membrane of the splenic corpuscles is formed by a prolongation from the sheaths of the small arteries, to which they are attached (fig. 40.) These small vessels are surrounded by a moderately thick sheath, which is chiefly formed of the pale, homogeneous, and flattened fibres, few of the curly elastic fibres being visible. These fibres run chiefly

FIG. 40.*

in the long axis of the vessel, and near to the point where the vesicle is attached the sheath becomes of a funnel-shaped form, being narrow at the point where it is connected with and surrounds the artery, but considerably broader and thicker just previous to its expansion into, and connection with, the membrane of the vesicles.

The fibres increase considerably in quantity at this part, and spreading out, crossing and diverging, are

* One of the splenic corpuscles from the spleen of the sheep, showing the structure of its external capsule, and its mode of connection with the bloodvessels.

continuous with similar fibres, which form the external membrane of the corpuscle; the fibres now crossing one another in almost every direction, and blending with one another, form a dense and finely delicate mesh, which covers the entire surface of the sacculus. The outer surface of this membrane also gives off prolongations, which invest the delicate vessels which run near to and on the surface of the vesicles. These fibres are not dissolved by a dilute solution of potash or ammonia, and if strong acetic acid be added to a portion so acted upon by either of these re-agents, the fibrous texture is still not dissolved, but is rendered rather more indistinct, and the spaces left between them dark and granular. The fibres are only indistinctly seen on the application of water, and are *almost entirely* dissolved by the action of acetic acid alone, a few remaining unacted upon. These results would apparently show the fibres to be of the *white inelastic variety of fibrous tissue*, a few only of the elastic fibres being present.

The delicate fibres composing the external membrane of the sacculus are so densely and intricately blended with one another, that they form minute and irregular meshes, somewhat of an hexagonal form, the interspaces being filled up by an exceedingly delicate and finely granular membrane. The margins of these mesh-like spaces present somewhat the appearance as if the membrane was composed of flattened cells or scales, united unevenly by their edges, as has been described by Saunders; but I believe that this appearance is mainly due to the fibres, which

cross the membrane in all directions, and which form the margins of the mesh-like spaces, as above stated.

ON THE RELATION OF THE SPLENIC CORPUSCLES WITH THE BLOOD-VESSELS.

FIG 41.*

The outer surface of the splenic corpuscles has a most intimate relation both with an arterial capillary

* This figure is intended to show the arrangement of the capillary plexus, on the exterior of the capsule of the splenic corpuscles.

plexus and also with the veins, a connexion which, as far as I am aware, has not been previously noticed by any anatomists. The blood-vessels ramifying on the surface of the splenic corpuscles consist of the larger ramifications of the arteries, to which the sacculus is connected, and also of a fine and delicate capillary net, similar to that surrounding the vesicles of other glands. On the arrival of the artery in connexion with the sacculus, it usually subdivides into two or more branches, and it is at their angle of bifurcation that the sacculus is attached. Some of these branches proceed in a straight course along the outer surface and sides of the vesicle, with generally but few subdivisions; others more rarely pass through the centre of these bodies, or through part of their circumference; these branches, on their arrival at the point where they proceed from the surface of the sacculus into the surrounding pulp, subdivide into tufts of small straight vessels, which ramify and anastomose in the substance of the pulp.

The vessels as they pass across the surface of the sacculus, are invested by a continuation of the common sheath, the fibres of which spread out on each side on the surface of the sacculus, blending with the fibres from the sheath of the neighbouring vessels, forming a dense and close net, through which the vessels pass. The vessels, also, as has been before said, on their leaving the surface of the sacculus, receive a thin and delicate prolongation from its general investing layer.

Besides the larger vessels already described, these

corpuscles are surrounded on their external surface by a close plexus of capillary vessels of extreme minuteness (fig. 41.) These vessels, which it is extremely difficult to demonstrate by injection, are derived either from one or more of the branches which cross the surface of the capsule, or from some neighbouring branch; they immediately break up into a mesh of delicate vessels, of equal size, which completely cover the entire surface of the capsule. The relation of this plexus with the wall of the splenic corpuscles allows most readily of the fluid ingredients of the blood permeating their wall, and consequently modifying, under certain conditions, the quantity and the quality of their contents.

The splenic corpuscles have an equally important relation with the *veins* (fig. 42). These vessels, which are of considerable size, even at their origin, commence on the surface of each vesicle, throughout the whole of their circumference, and exist in such numbers as to form a dense venous mesh, in which each of these bodies is enclosed. These veins, diverging from their circumferenee, unite with neighbouring vessels of similar size; whilst these latter empty themselves into the large venous trunks traversing the substance of the pulp. I think that this relation of the veins with the splenic corpuscles assists materially in explaining their function. It has been already seen, that under certain conditions these glands vary considerably in size, and also in number; that in some cases they become distended with the peculiar secretion which they contain; whilst under opposite con-

FIG. 42.*

ditions, they are so small as to be invisible to the eye. In the arrangement of the bloodvessels of these glands we see every adaptation for these changes; they are provided with an arterial capillary net of the most extreme minuteness, capable of secreting the

* This figure is intended to show the connection of a splenic corpuscle with the neighbouring vessels. The corpuscle is seen to be placed at the angle of bifurcation of one of the small arteries, its external surface being covered by a close and delicate capillary plexus, whilst its circumference is invested by a mesh of large veins, which radiate in every direction from its margins. The comparative size of the arteries and veins, the capillary plexus of the pulp, and the mode in which these vessels communicate with the veins, are shown in this figure.

material occasionally stored up in their cavity. They are surrounded by a dense and complex venous mesh, capable of carrying off, under certain conditions, those contents that are again to be discharged into the circulation.

Are they connected with the Lymphatics?

The result of my investigations on the external membrane of the splenic vesicles has shown them to be perfectly closed cavities, consequently the lymphatic vesicles can have no direct communication with them. They cannot then serve to convey away directly the materials enclosed in these cavities after the manner of excretory ducts, excepting by a dissolution of their wall, although such an opinion was held by Hewson in earlier time, and more lately by Home, Giesker, Huschke, Evans, Gerlach, and Poelmann.

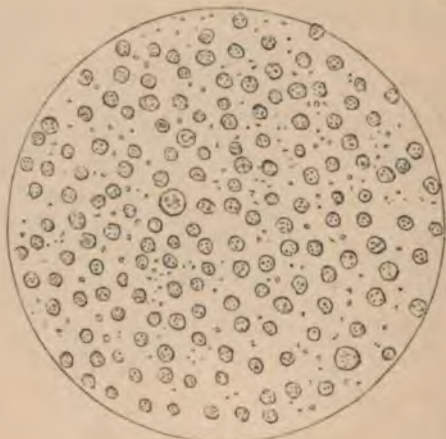
CONTENTS OF THE SPLENIC CORPUSCLES.

I must now, in the next place, consider the structure of the contents of these glands, and their chemical composition, as far as can be determined by the application of chemical reagents.

When the splenic corpuscles, previously cleaned from the surrounding pulp, are compressed, there issues forth a translucent fluid, of a whitish colour, in which numerous solid corpuscles are suspended. The plasma in which the corpuscles are held consists of a

mass of exceedingly minute and fine dark granules; it is of a whitish colour, semi-fluid, and translucent. Numerous minute free dark granules may sometimes be observed in it.

FIG. 43.*



The solid contents are:—

1. Amorphous and finely granular matter. This is a fine granular blastema, in which the nuclei are interspersed; in this, a few highly refractive globules may occasionally be observed.

2. Nuclei precisely similar to those found in the pulp (fig. 43); their size *varies* from the 2000th part of an inch to the 5000th, the average size being about the 3500th. Their *form* varies as much as their size—the great majority are of a flattened circular

* Dotted nuclei from the interior of the splenic corpuscles. From the spleen of the rat.

form; these are generally the largest corpuscles, and it is in these that the nucleoli, or granules, are to be observed most distinctly. Others, and these chiefly the smaller ones, are somewhat less circular, their sides or edges being flattened and more irregular; in these the nucleoli are less distinct, although they may still be observed. Some also present an elongate oval form; they are much paler than those just described; their margin, although distinct, is less darkly defined, their contents being two, three, or several fine pale granules. Nuclei similar in character to those above-mentioned, varying considerably in size, and around some of which a faintly delicate cell wall, enclosing a few granules, may be observed; these were, however, to be rarely met with; but around many nuclei a quantity of fine granular plasma is arranged in an imperfect circular form, and without any distinct vesicular envelope; these exist occasionally in *very large* quantities. The external margin of these nuclei is darkly lined, and distinct, and generally perfectly regular in their outline, whilst in the interior is seen either a single dark and highly-refractive nucleolus, or two nucleoli, or more frequently three, four, or five small dark, dotted granules, which present, in some cases, so high a refractive power, as to bear much resemblance to fat granules. The swollen nuclei exhibit less distinct traces of nucleoli, or granules. These form the chief constituent of the contents of these vesicles.

3. Nucleated cells : these form only a very small proportion of the corpuscular elements; their form is

circular, and their size about the 2000th part of an inch in diameter; they consist of an outer vesicular envelope, having a circular-shaped nucleus on its wall, similar to those above.

4. In the sheep may be seen nuclei of an elongate oval form, paler than the other elements, and containing a varied number of fine pale granules; they vary in size, but they are larger than the nuclei themselves.

I could not detect any separate blood discs or blood discs enclosed in cells among the contents of these vesicles, under any circumstances; I cannot, consequently, but conclude that they never form a part of their normal contents.

The above-described elementary structures, which form the sole contents of the splenic corpuscles, present, occasionally, very considerable variation in their *amount*, under certain circumstances, and not only does the quantity of the whole vary, but the several elements present themselves in unequal quantity at certain periods. Occasionally, and, in fact, chiefly, the nuclear structures predominate; at other times, again, a much larger quantity of nuclei, with granular matter arranged around them, or even nucleated vesicles, make their appearance. These facts, I think, evidently shew that, under certain circumstances, a continuous process of cell development, of cell growth, and dissolution takes place in the splenic corpuscles, as in the pulp, wherein nuclei are formed, around which a granular plasma is arranged, and after which both nuclei and plasma break up and disappear, probably forming the amorphous

blastema in which the nuclear structures are contained.

I will now consider the composition which these elements present, as far as the application of chemical re-agents will determine.

Acetic acid reduces the size of the nuclei considerably, renders their margins and contents darker, and dissolves the plasma or imperfect granulo-cellular envelope surrounding them (when it exists).

Sulphuric æther partially dissolves the nuclei into a dark amorphous granular mass, and at the same time partially dissolves the granular matter surrounding them; the undissolved nuclei are somewhat wrinkled, and present a darker aspect.

Liq. potassæ and liquor ammoniæ completely dissolve both the nuclei and granular plasma contained in the corpuscles, and render the vesicular membrane and contents *perfectly transparent.* The addition of acetic acid now *restores* the *white* opaque appearance of the capsule and contents. The capsule loses its transparency, presents a darkish granular appearance, and a fine pale amorphous plasma is observed in the place of the nuclei and blastema.

The complete dissolution of the contents of these vesicles by means of liquor potassæ and liquor ammoniæ, and their subsequent re-precipitation by acetic acid, distinctly prove them to be *a proteine or albuminous compound.*

As far as our investigation has at present proceeded, it has been seen that the splenic corpuscles, which form a large portion of the substance of the spleen,

and which at certain times exist in considerable numbers, and of large size, consist of an *albuminous* or *proteine compound*, represented by an orga ised tissue which passes through certain stages of cell-development, growth, and dissolution, contained in a perfectly closed capsule, connected with the larger arteries, and completely covered on their outer surface by a dense but delicate capillary net, in such a manner that the liquor sanguinis of the blood, permeating them, may easily be exposed so as to influence their contents, and secrete the matters contained in them; the dense venous mesh surrounding these bodies being so arranged as to take up, under certain conditions, the contents of these vesicles, which their diminished size shows that they discharge under certain circumstances.

It has already been seen that not only do the elements themselves, contained in the vesicles, differ in their structure at certain periods, but what is also of very considerable importance, that the amount of these elements varies *considerably* under certain circumstances.

I shall now attempt to consider the laws which regulate these extreme differences in size. What is it that determines in one case their repletion, in another case their emptiness?

The experiments that I am about to detail, will, I think, show, that the variation in the size of these bodies is dependant—

1st, upon the state of nutrition of the animal generally.

2nd, upon the period of the digestive act.

3rd, upon the kind of aliment introduced into the system.

4th, upon the presence or absence of fluids introduced with the food.

The *state of nutrition* of the animal influences to a very considerable degree the size of these bodies, and consequently the amount of their contents. It may be stated as a result of very numerous experiments on *cats, rabbits, and rats*, that the *maximum of size* is attained in all those animals in which the nutrition of their bodies was in a most perfect condition, and where a greater amount of new material was added to the system than was required for the expenditure and waste of the body. On the contrary, in *ill-fed*, or more particularly in *starved* animals, they were in all cases reduced to their *minimum of size;* they were, in fact, almost totally absent. For a detailed account of some of the experiments on rabbits and rats, see below.[1]

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[1] *Experiment* 1.—A full-grown rabbit was starved for ten days. It was then killed. The weight of the spleen was *three grains.* The splenic corpuscles could hardly be discerned by the naked eye.

Experiment 2.—A full-grown rabbit was well fed on bread, milk, and oats, for *six days* before death. The animal was then killed. The weight of the spleen was eleven grains. The splenic corpuscles were very large, numerous, and completely distended with nuclei.

Experiment 3.—A full-grown rabbit was well fed on bread, milk, and green meat for *a month* before death. The weight of the spleen was nineteen grains. The splenic corpuscles were very large, and completely distended with nuclei.

Experiment 4.—A *young* rabbit was starved to death. It died

The result of these experiments would appear to show, that the splenic corpuscles store up a large quantity of *proteine* or *albuminous* compounds, when the system is in a highly nutritious state, and that

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in four days. The weight of the spleen was three grains; its proportion to the body being as 1 to 2700. The splenic corpuscles were not visible to the eye.

Experiment 5.—A young rabbit, of the same age as the above, was well fed for a month before death. The weight of the spleen was fourteen grains; its proportion to the body being as 1 to 1070. The splenic corpuscles were numerous, very large, of a white colour, and distended with nuclei.

The two next experiments illustrate the variation in the size of the splenic corpuscles, according to the period of the digestive act.

Experiment 6.—A large healthy rat was fed upon bread and milk for a week, the last meal being given fifteen hours before death.

				Proportion to Body.
Weight of Spleen	was	16 grains	...	as 1 to 288
„ Liver	„	317 grains	...	as 1 to 14
„ Kidneys	„	44 grains	...	as 1 to 104

The splenic corpuscles were very large and numerous, and of an opaque white colour. The liver contained a very large quantity of fat. Its enormous size apparently depending on this organ containing a considerable accumulation of this element.

Experiment 7.—A large healthy rat was fed upon bread and milk for a week. The last meal was given *forty-eight hours* before death.

				Proportion to Body.
Weight of Spleen	was	9 grains	...	as 1 to 323
„ Liver	„	82 grains	...	as 1 to 35
„ Kidneys	„	30 grains	...	as 1 to 97

In this experiment the splenic corpuscles were *very indistinct.* The liver contained *no fat.*

The diminution in the weight of the liver appeared to depend

they restore this again to the blood during the demand required under the opposite condition.

The period also of the digestive act modifies very

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on the absorption of this element from the organ, to be used, probably, by the respiratory organs.

The next seven experiments will illustrate the variation in the number and size of the splenic corpuscles, as influenced by the kind of aliment introduced into the system.

Experiment 8.—*Mixed Diet.* A healthy rat was well fed on milk, bread, fat, and meat, for ten days. He was then killed, the last meal being given *three hours before death.*

Stomach full of food. Intestines empty. No chyle in lacteals.

					Proportion to Body.
Weight of	Spleen	was	11 grains	...	as 1 to 219
„	Liver	„	128 grains	...	as 1 to 18
„	Kidneys	„	20 grains	...	as 1 to 120

The splenic corpuscles were large, pearly white, and distended with dotted nuclei.

The large size of the liver appeared to depend on the *considerable amount of fat* contained in it.

Experiment 9.—*Albuminous Diet.* A rat was fed on boiled white of egg, for eight days, eating two eggs daily. He was then killed.

					Proportion to Body.
Weight of	Spleen	was	13 grains	...	as 1 to 250
„	Liver	„	195 grains	...	as 1 to 16
„	Kidneys	„	26 grains	...	as 1 to 125

The splenic corpuscles were of large size, numerous, and distended with nuclei. *No fat* was found in the hepatic cells.

Experiment 10.—A rat was fed upon boiled white of egg for ten days. It was then killed.

					Proportion to Body.
Weight of	Spleen	was	11 grains	...	as 1 to 270
„	Liver	„	142 grains	...	as 1 to 17
„	Kidneys	„	36 grains	...	as 1 to 115

The splenic corpuscles were large and distinct.

Experiment 11.—*Fibrinous Diet.* A rat fed on flesh meat died

considerably the state of repletion of these bodies; they in all cases present a large size during the latter periods, and after the final completion of the

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in six days. Eat in that time about two ounces. The body had much wasted.

				Proportion to Body.
Weight of Spleen	was	3 grains	...	as 1 to 547
„ Liver	„	48 grains	...	as 1 to 34
„ Kidneys	„	17 grains	...	as 1 to 96

The splenic corpuscles were not visible to the naked eye.

There was *no fat* in the hepatic cells.

Experiment 12.—A rat fed on flesh meat died in five days.

				Proportion to Body.
Weight of Spleen	was	5 grains	...	as 1 to 500
„ Liver	„	60 grains	...	as 1 to 32
„ Kidneys	„	22 grains	...	as 1 to 103

The splenic corpuscles were not visible.

There was *no fat* in the hepatic cells.

Experiment 13.—*Fat Diet.* A rat was fed on fat. It died in ten days. Much wasted. White chyle in lacteals and thoracic duct.

				Proportion to Body.
Weight of Spleen	was	3 grains	...	as 1 to 563
„ Liver	„	57 grains	...	as 1 to 29
„ Kidneys	„	16 grains	...	as 1 to 105

The splenic corpuscles were *not* visible to the naked eye.

The liver contained a *large quantity of fat.*

The other experiments gave a precisely similar result.

Experiment 14.—*Diet of Gelatine.* A rat fed on gelatine died in four days. Much wasted.

				Proportion to Body.
Weight of Spleen	was	4 grains	...	as 1 to 550
„ Liver	„	60 grains	...	as 1 to 30
„ Kidneys	„	18 grains	...	as 1 to 118

Splenic corpuscles not visible.

The liver contained *no fat.*

Other experiments gave similar results.

digestive act, after in fact the new material has been introduced into the circulation, and has become converted into blood; their size, on the contrary, being much diminished at an *early period* of the digestive act, or *some long time* after its final completion. It is, however, to be observed that their large size does not in all cases depend *entirely* upon the period of the digestive process, for in animals *starved for some days, and* THEN *fed*, their size is very *inconsiderable*, as compared with those in which normal nutrition had previously been carried on uninterruptedly.

The kind of aliment introduced into the system modifies considerably the size of the splenic corpuscles, whilst it affords at the same time additional proof of their contents being of an *albuminous nature*.

Rats which had previously eaten a mixed diet, were fed on pure albumen (boiled white of egg) for several days. This change of diet did not in the least affect their healthy condition. At the end of a week they were killed, and in each case the splenic corpuscles were of *considerable size* and *distended* with their peculiar contents. The proportion the spleen bore to the body being *as* 1 *to* 250. Several rats (three) were fed for several days upon meat (fibrin) deprived of skin and fat. The change of diet in each of these cases materially affected the health of the animal; they became much wasted, and died, on an average, six days from the commencement of the experiment. The splenic corpuscles were *hardly distinguishable* by the naked eye. The proportion the spleen bore to the body was *as* 1 *to* 547.

Rats which had also previously eaten a mixed diet were fed with fat for several days; they lived, on the average, about ten days, dying much wasted; in fact, much in the same state, apparently, as those fed upon fibrin. The splenic corpuscles were *not visible* to the eye. The proportion the spleen bore to the body was *as* 1 *to* 563.

Lastly, three rats were fed upon *gelatine.* In each case the animal died apparently of starvation, the bodies becoming much wasted, and death occurring on the fourth and fifth days. The splenic corpuscles were not visible to the naked eye. The proportion the spleen bore to the body was *as* 1 *to* 550.

Several important results are to be derived from these experiments. They show, in the first place, that where a sufficient supply of nutriment is withheld from the animal, or where its quality is such as not to be adequately fitted for the requirements of the system, not only does the spleen diminish considerably in its size, but the splenic corpuscles, which, under opposite conditions, store up a quantity of albuminous matters, become of diminutive size from their giving up again to the blood that which they had for a time retained. The fact, also, of these bodies becoming of considerable size during the exhibition of a purely albuminous diet, assists in proving that the contents consist essentially of an albuminous compound.

The presence or absence of fluids introduced with the food also influences considerably the *size* of these bodies.

Three healthy rats were fed for several days on bread soaked in a *large quantity of water*. On being killed, the splenic corpuscles were found of *large size*, and distended with their semi-fluid contents.

Three other rats were fed on bread previously dried, not the least amount of water being given; they were also killed at the same time, and at the same period after the ingestion of food as the other rats. In each of these, the splenic corpuscles were *smaller*, and their *contents less fluid* than in the former experiments.

The introduction of water, it appears from these experiments, modifies *the size* and *fluidity* of the contents of these vesicles.

We have now completed our investigation of the structure of these bodies, the structure of their contents, their chemical composition; we have examined into the laws which regulate their extreme variation in size under certain circumstances; let us lastly inquire, What is the nature of these vesicles? Do they correspond with those of the other blood glands, and what function do they perform?

The results of my observations on the development of the splenic corpuscles, as well as the structure which they present in their mature state, I think afford sufficient evidence of their glandular nature, and of their close similarity with those of the other ductless glands. With regard to their development, it has been already seen that they are formed in a precisely similar manner with the vesicles of the other ductless glands; first, by the aggregation of a

mass of nuclei with one another; secondly, by the formation of a delicate limitary membrane around them, and although the structure of the membrane of these vesicles in the mature stage differs somewhat from those of the other ductless glands, in the existence of a delicate coat of white fibrous tissue in the place of a structureless limitary membrane, still the essential parts of those vesicles, their contents, are precisely similar in structure, and are arranged also like those elements in the vesicles of the supra-renal and thyroid glands. Like them, also, they are completely enclosed by a delicate capillary net, so that the fluid traversing these vessels, and permeating their walls, may have the freest access to the interior, regulating the degree and extent of the secretion contained within their cavity. Their intimate connection, also, with a dense venous mesh, which completely envelopes their exterior, is an evident adaptation to the requirements of these bodies, serving to carry off, at certain periods, the matters stored up in their cavity. Their function, also, appears to be like that of the vesicles composing the allied glands, serving to store up in their cavities at certain times, and under certain conditions, a proteine compound, which is, under other conditions, again restored to the blood. From these facts, I should infer that the spleen vesicles are a peculiar kind of closed glandular vesicle, analogous to those of the other ductless glands, and consequently with which they may be allied.

ON THE LYMPHATICS OF THE SPLEEN.

THE discovery of the origin and course of the lymphatic vessels of the spleen, as well as the composition of the lymph, has always been regarded by physiologists as a most important aid in elucidating the function of the spleen; and the large size of these vessels in some animals has led many to consider them as the channel by which peculiar products elaborated in that organ may be carried into the circulation; nor can it be conceived that such an opinion was improbable, as no *special* channel exists by which any substances changed or formed in this organ can be carried into the blood. My investigations on these vessels, and on the lymph, have been confined almost entirely to the human subject, the horse, and ox.

In my description I shall consider the anatomy of these vessels first in the *horse*, and afterwards in the *human subject*. In the horse, as in all animals, the lymphatics form two sets, a superficial and a deep. I shall, in the first place, consider the origin of the *superficial* lymphatics, and then of the *deep* set; I shall then describe their course and termination; lastly, I shall describe the lymphatics of the human subject, and the composition of the lymph.

ORIGIN OF THE SUPERFICIAL LYMPHATICS.

The lymphatic vessels on the *surface* of the spleen are situated in the subperitoneal areolar tissue,

between the peritoneum and fibrous coats. So far as mercurial injection informs me,[1] I have observed them in numerous instances as commencing by an exceedingly delicate *network* of vessels, which present a perfectly regular cylindrical form, and which neither terminate by free closed extremities, nor by small cellular cavities; the latter appearance only being produced when they are much distended, the meshes between the vessels being smaller than the diameter of the lymphatics which form them. They are easily injected from one of the smaller trunks, as they are not provided with valves; this plexus completely covers every part of the external surface of the organ, the vessels composing it in certain situations joining together to form *larger trunks;* they are confined entirely, as far as my observations go, to the surface, none either passing into, or communicating with the lymphatics in the interior.

ORIGIN OF THE DEEP LYMPHATICS.

I have not been able to demonstrate with the same certainty the *origin of the deep* lymphatics, a difficulty chiefly depending upon the total impossibility of injecting the smaller vessels from the larger trunks, which are provided with numerous valves. These vessels, in the hilus of the spleen, and also for some little distance in the *interior* of the organ, accompany the blood-vessels, and are contained in the loose

[1] The preparations illustrating the origin and course of the lymphatic vessels are now deposited in the museum of Guy's Hospital.

areolar tissue which constitutes their sheath; in this situation I have injected them; they consist of *large* but not very numerous trunks, which anastomose with one another at varied intervals. They are neither so small nor so few in number as is usually described. On their emerging, they join with the superficial lymphatics.

I endeavoured, in the next place, to ascertain if the deep lymphatics had any connection with, or origin from the more essential parts of the organ, as the splenic corpuscles and the pulp, a point of very considerable importance from the frequency with which many anatomists[1] have stated such a connection to exist. It has already been seen that the splenic corpuscles are perfectly *closed* capsules, so that they cannot be, as supposed by some, the dilated commencement of these vessels; neither have I observed on their external surface, or in the sheaths of the vessels to which they are connected any trace of lymphatic vessels. From these circumstances I conclude that the splenic corpuscles are in no way in direct communication with the lymphatics, which consequently cannot be considered as fulfilling the office of excretory ducts, in carrying off the secretions. In the *pulp* of the spleen I have also failed to discover any existence of lymphatic vessels. Their absence in these situations would render it not improbable that they arise in a similar manner to the superficial lymphatics, by a plexus in the sheaths of the more delicate vessels.

[1] *Gerlach. Poelmann. Schaffner. Evans.*

ON THE COURSE OF THE LYMPHATICS.

The minute lymphatic plexuses on the *dorsum* of the organ unite to form numerous small trunks, which cover a very considerable portion of its outer surface. These trunks are at first of equal diameter, lie parallel with one another in rows of few or many branches, and unite at varied intervals; they proceed in every direction from the *centre* towards the *circumference* of the organ, in their course joining with one another to form vessels of *very considerable size*, which are now provided with numerous valves. The junction of these vessels with one another, more particularly on the dorsum of the organ, is so frequent, that the most complete communication between the vessels covering its entire surface must take place. The larger trunks, on arriving at the margin of the *circumference* of the organ, curve round to its *under* surface, where they join with many branches formed by similar plexuses on this surface, and attain now a very considerable size, more particularly at the posterior part of the organ; when they arrive at the hilus of the spleen the course of these vessels is variable, some of the *smaller* trunks pass between the layers of the gastro-splenic omentum; but the *larger* ones accompany the vessels along the hilus of the organ, forming in their course three or four trunks, which vary in size from a crow's quill to a goose's quill. In their course through the hilus these vessels pass through numerous lymphatic glands, which vary

considerably both in number and size; they unite also with those from the interior of the organ; and finally form four large trunks, whose united diameter is larger than that of the splenic artery; these terminate in the receptaculum chyli, just at the point where it becomes the thoracic duct.

The above observations on the spleen of the horse apply equally to the ox, in which I have also demonstrated them.

In none of the numerous injections that I have made have I been able to trace any communication between the lymphatics and the veins; in no single instance was the injected material found in these vessels; neither have I observed, after the most minute injection of the blood-vessels, whether arteries or veins, any trace of the injected material in the lymphatic vessels.

LYMPHATICS IN THE HUMAN SUBJECT.

In *man* the lymphatics are neither numerous nor of large size, affording a striking contrast with those vessels in the ruminantia and the horse; they form, however, as in those animals, a superficial and deep set. The *superficial* lymphatics, from their small size, and from the intimate adhesion that exists between the peritoneal and fibrous coats, are exceedingly difficult of demonstration. It is probable their origin is the same as in the horse. They may be seen to consist of a few delicate anastomosing trunks, which run from the centre to the circumference of

the outer convex surface of the organ, winding round the margin to its under surface, and on their arrival at the hilus, where they are more distinct from their larger size, uniting with the *deep* lymphatics. The *deep set* may *occasionally* be seen emerging with the bloodvessels at the hilus. I have not been able, however, to trace them into the interior of the organ, on account of their exceedingly minute size. They join with the superficial lymphatics at their point of *emergence*. These vessels now form small trunks, which accompany *each* of the divisions of the splenic artery, entering in their course the lymphatic glands in the hilus, and finally unite together to form a trunk, which empties itself into the thoracic duct.

The *structure* of the lymphatic vessels does not present any peculiarity worthy of notice, as different from the structure of lymphatic vessels generally. Valves are found both in the deep as well as in the superficial lymphatics.

OF THE LYMPH.

The *lymph* contained in the lymphatics differs considerably in the *superficial* and *deep* vessels, both as regards its *colour*, and *microscopic characters*. It also differs very much as to its *quantity* at certain periods.

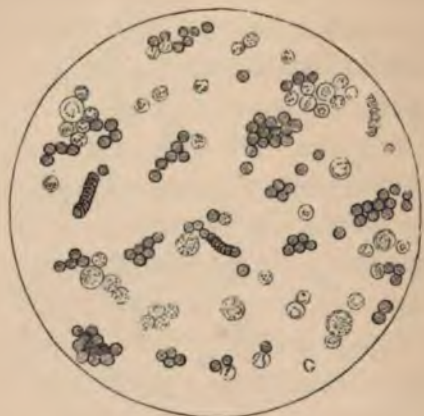
In the *superficial lymphatics* (fig. 44), the lymph is in all cases in which I have observed it, a *pale*, *straw-coloured* fluid, in many cases containing only an *exceedingly small* number of lymph corpuscles. These are circular, about equal in size to the blood discs;

FIG. 44.*

they are pale, colourless, and consist apparently of a faintly granular mass, in which no nucleus becomes apparent until acetic acid is added; then a small dark and irregular-shaped body occupies the centre, a space intervening between it and the cell wall. It also contains numerous *minute* granules of varying shape, some few of which are darkly refractive. A few normal blood corpuscles may also occasionally be observed, and generally a small quantity of dark blood-red, reddish-brown, or black pigment granules, which vary much in form and size. The lymph from the *deep* lymphatics (fig. 45), was also, in all cases in which I observed it, a *reddish*-yellow transparent fluid, having precisely the same colour *both before* and *after*

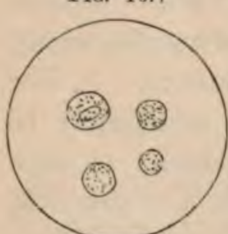
* This figure is intended to illustrate the microscopic structure of the lymph from the superficial lymphatics.

FIG. 45.*



its passage through the glands in the hilus. This colour appeared totally to depend on the presence of a number of blood corpuscles.

FIG. 46.†



The lymph globules are far *more numerous* than was found in the superficial lymphatics; they are of two kinds (fig. 46). The most numerous vary in size, from the 3300th to the 5000th of an inch in diameter; they are pale, colourless, spherical in form, and when unacted upon by acetic acid consist apparently of a faintly granular mass; on the addition of this acid

* This figure illustrates the microscopic structure of the lymph from the lymphatic vessels in the hilus.

† Lymph corpuscles from the deep lymphatics, more highly magnified, in order to show their minute structure.

FIG. 47.*

(fig. 47), they become darker, and disclose to view the appearance either of a single or double nucleus in their centre. The least numerous, which are the largest, have an average diameter of about the 2500th of an inch. They have a spherical form, and a fine pale granular structure. On the application of acetic acid a single irregular-shaped and dark-edged nucleus is observed, with a distinct space intervening between it and the cell wall. Granules similar both in size and form to those found in the lymph from the superficial lymphatics are also to be observed, and it contains numerous dark red or reddish brown pigment granules.

With regard to the existence of blood corpuscles in the lymph, it appears very probable that they depend upon some communication that exists between the smallest capillary and lymphatic vessels of the organ, where considerable congestion, and probably consequent rupture of the vessels not uncommonly occurs. In some organs actual communication between these two sets of vessels has been observed to occur, depending, however, either on abnormal formation or rupture.

* Lymph corpuscles acted upon by acetic acid, showing the apparent nucleus which they contain.

QUANTITY OF LYMPH.

The *quantity* of lymph contained in the lymphatics of the spleen varies considerably at certain periods, and under certain circumstances. I have observed in horses, where the organ is much distended with blood in artificially impeded respiration, hardly any *lymph* in these vessels; only a *small* quantity was seen during the various periods of the digestive process. On keeping horses, however, without food for a considerable period (two days), the gradual diminution of the *size* of the organ during this period was in all cases accompanied with an almost abnormal distension of these vessels with their peculiar fluid.

COMPOSITION OF THE LYMPH.

When we consider the large size of the lymphatic vessels in some animals, and consequently the great amount of lymph that must constantly be carried off from the spleen, it becomes a very highly important point to discover the physical properties and chemical composition of this fluid, in order to ascertain if it in any way differs from lymph obtained from other organs. That the lymph secreted by the spleen was in some way peculiar, and that it differed from that obtained from other sources, was maintained by Hewson, Tiedmann, and Gmelin, and more lately by Gerlach, Spring, Poelmann, and Schaffner,[1] all of whom

[1] See *Bibliography and Historical Introduction.*

maintain that this fluid in some way or other serves to form *blood corpuscles*.

In order to render these investigations as perfect as possible, and to test the accuracy of these statements, I determined to examine the general properties and chemical composition of this fluid. Having previously ascertained that the activity of the lymphatic vessels was greatest during the withdrawal of food, three horses were deprived of food for twenty-four hours, and the amount of lymph that was obtained from the lymphatic vessels was about six drachms. This fluid was taken partly from the large *superficial* trunks, and partly from the *deep* lymphatics in the hilus. The fluid, which was carefully drawn off, so as to prevent the admission of any blood, was of a reddish yellow tinge, and separated in about ten minutes into a firm solid clot, which floated in a yellowish serous fluid. It presented the following composition.

Analysis of Lymph from the Superficial and Deep Lymphatics of the Spleen in the Horse.

Water	93·380
Solids	6·620
	100·000
Solids, consisting of	
Albumen	5·475
Fibrine	·236
Red Corpuscles	trace
Fat	trace
Salts, consisting of Chloride of Sodium, Phosphates, and Iron	·909

The results of this analysis appear to be of a highly important nature, as it distinctly proves that this fluid is in no way different (excepting in the small amount of blood globules which it contains) to the composition of lymph obtained from other organs, and consequently the quality of the lymph formed in the spleen cannot in any way serve as a clue in explanation of the peculiar function of this organ.

There is no doubt, as *microscopic* examination and *chemical analysis* have both shown, that the reddish colour of the spleen lymph depends almost entirely on the existence of a small number of blood corpuscles in this fluid, and it is partly from this circumstance, as well as its coagulability, that the theories maintained by Hewson, Tiedmann, and Gmelin, and their followers have been founded—viz., that the spleen serves to *form* the blood corpuscles, which are conveyed away by the lymphatic vessels.

The coagulability of the splenic lymph cannot, however, be regarded as in any way peculiar, as lymph obtained from other sources, as I have frequently observed, also separates into clot and serum.

With regard to the existence of blood corpuscles in the lymph, although, as I have observed, their occurrence is *constant*, and *not* exceptional, as may be easily seen in those animals where the lymphatics are of large size, as the horse, ox, and calf, still their *quantity*, as shown in the above analysis, is so inconsiderable, that it would be impossible to conceive that the function of the spleen was to serve in their formation. Moreover, the reddish colour of the spleen

lymph is not peculiar to this organ; for I have found this fluid in some cases presenting exactly the same tinge, both in the liver and also in the kidneys, and in both cases depending upon the same cause, the existence of blood corpuscles.

Again, the blood in the lymphatic vessels of the spleen in *all* cases presents the appearances of the *perfectly-formed* corpuscles, in no case is *their formation* to be traced out in this fluid. There could not exist, however, more positive proofs *against* the above-mentioned theory than the constant existence of the disintegration or dissolution of the blood corpuscles in this organ; a fact, the constant occurrence of which, in nearly all cases and under nearly all circumstances, as well as in all the various classes of the vertebrate animals, must greatly militate against the accuracy of the above-mentioned theory. If I add to all these facts the results of the analyses of the emerging blood of the spleen, as compared with that which enters the gland, where the extreme diminution in the amount of the blood corpuscles is one of the most prominent features, a feature also in exact accordance with the above-mentioned observations on the minute anatomy of the organ, I think I am justified in concluding that the lymph of the spleen is in no way different from that obtained from other organs; and that consequently the theories which ascribe to the organ a relation with the lymphatic system, or with the formation of blood corpuscles, are without foundation; and that its analysis affords no clue to our determination of the function of this organ.

But it may be asked, In what manner do the blood corpuscles obtain entrance into the lymphatic vessels? As I have attempted to show above, there is no doubt that some communication exists, either by actual anastomoses between the lymph and bloodvessels, dependent upon a primitive abnormal formation, or else, which is far more probable, the communication existing between them is caused by rupture of the delicate capillary network of the organ, and the finest lymphatic vessels; a circumstance which must very probably frequently occur during the very highly congested state, which is constantly occurring in this organ.

ON THE FUNCTION OF THE SPLENIC LYMPHATICS.

Having determined that these vessels do *not* carry off *any secretion* formed either in the pulp or Malpighian corpuscles of the spleen, after the manner of excretory ducts, it appears probable that the only office they can perform is to remove the superfluous parts of the liquor sanguinis effused through the delicate capillary network, and destined to nourish the tissues of the organ; and that the *large* size of the lymphatic vessels, destined for this peculiar office, stands merely in exact relation with the *large* size of the vessels destined for its nutrition.

ON THE NERVES OF THE SPLEEN.

In treating of the anatomy of the nerves of the spleen, I shall first describe them in the human subject, and then mention the peculiarities that are met with in the lower animals. In this description I shall, in the first place, consider their *origin;* secondly, their *course;* thirdly, their *distribution;* and lastly, their *minute anatomy.*

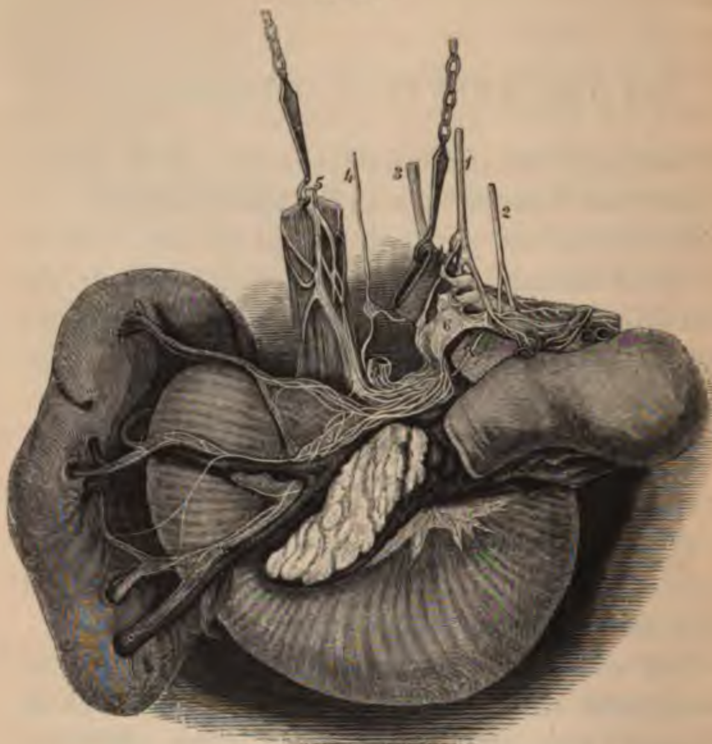
ORIGIN OF THE SPLENIC PLEXUS. (Fig. 48.)

The splenic plexus is formed by branches from the right and left semilunar ganglia, and also by branches from the right pneumogastric nerve.

The branch from the *left* semilunar ganglion is of *considerable* size, being about the 16th of an inch in diameter; soon after its origin it unites with the branch from the right ganglion, and then, arriving at the trunk of the splenic artery, just at its origin from the cœliac axis, divides into several (5) branches; all of these pass on to the trunk of the artery to assist in forming the splenic plexus.

The branch from the right semilunar ganglion, (not previously described,) is merely a filament of very small size, but of considerable length; arising from the upper part of the ganglion, it passes transversely from right to left in front of the aorta and inferior vena cava, and joins with the branch from the left

Fig 48*



* The origin, course, and distribution of the splenic plexus of nerves in the human subject are shown in this figure.

1. Great splanchnic nerve (left).
2. Lesser splanchnic nerve (left).
3. Great splanchnic nerve (right.)
4. Right phrenic nerve, communicating with the hepatic plexus.
5. Pneumogastric nerves.
6. Left semilunar ganglion.
7. Branch from right semilunar, which assists in forming splenic plexus.
8. Splenic artery and plexus of nerves surrounding it.
9. Hepatic artery and plexus of nerves surrounding it, the phrenic communicating with this plexus.

From a dissection of the author's in the museum of Guy's Hospital.

ganglion, just before its division on the surface of the artery. The filaments from the pneumogastric are not derived *directly* from the *trunk* of the nerve, but may be traced from the nerve through the left semilunar ganglion, from the surface of which they pass on to the trunk of the splenic artery, and join there with the branches derived from the sources already stated. These filaments are two in number, and of extreme delicacy; it is by the union of the branches derived from these sources that the splenic plexus is formed.

COURSE OF THE PLEXUS.

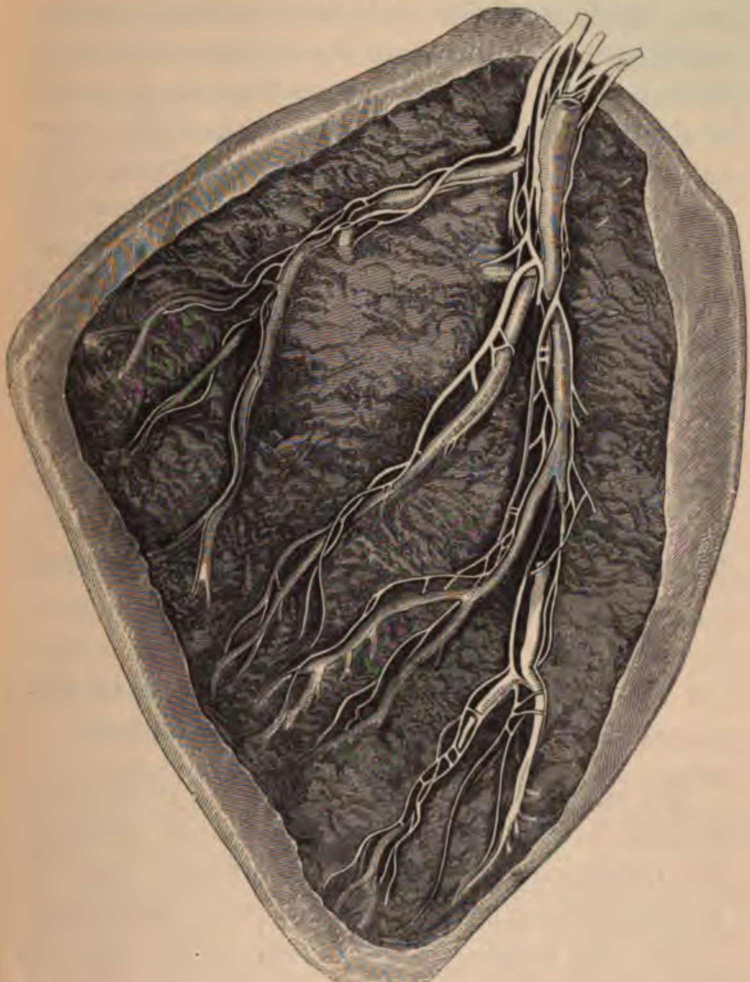
The branches derived from the above-mentioned ganglia and nerves, on arriving on the trunk of the artery, subdivide into very numerous filaments, which immediately uniting form a delicate and intricate plexus of nerves which surrounds the entire circumference of the trunk of the artery, being contained in the loose cellular tissue forming its sheath; these branches, by subdivision, having increased considerably in number, form as many as eight or nine filaments, which lie in close proximity with the wall of the artery, and accompany it to its division into its three primary branches. From these filaments a few fibrillæ are derived, which accompany the pancreatic branches of the artery given off from the vessel as it runs along the upper border of the pancreas. Each of the primary branches of the splenic artery receives from the plexus from four to six branches, which accompany the arteries interlacing with one another, at numerous

points; these finally become more delicate, but still form an exceedingly minute plexus, which surrounds each of the secondary branches of the artery, upon which they may be traced as far as the hilus of the organ. At the point where the vasa brevia and gastro epiploic arteries are derived from the splenic, several small filaments from the splenic plexus are found to accompany them, and are distributed with these vessels to the textures into which they pass. I have not been able to discover the existence of any ganglia, either on the branches forming the plexus, or on the branches of the plexus itself, either external to the organ or in its interior.

ON THE DISTRIBUTION OF THE PLEXUS IN THE INTERIOR OF THE SPLEEN. (Fig. 49.)

The extreme delicacy of the nerves in the *human subject*, and their minute size, totally prevent their distribution being *clearly* demonstrable in the *interior* of the organ. Under these circumstances, I have examined the distribution of the nerves in some of the lower animals (as sheep, oxen, horses), where, from their enormous size, their course can be satisfactorily demonstrated. In the first-mentioned of these animals, which I have more particularly examined, the nerves are of very considerable size, more particularly as compared with those in the human subject. When they pass into the substance of the organ with the splenic artery, they are contained in the sheath of that vessel, and consist of three large trunks, which,

Fig. 49.*



* The distribution of the splenic plexus of nerves in the interior of the spleen in the sheep, is shown in this figure. It is seen to consist of very numerous and large branches, which accompany the ramifications of the splenic artery to their ultimate distribution. From a dissection of the author's in the museum of Guy's Hospital.

taken together, equal its diameter. These branches immediately subdivide, and reuniting, form a plexus, which completely surrounds the artery in the interior of the organ, giving off numerous filaments upon each of the branches into which the trunk of the vessel subdivides, forming thus a complicated plexus, which ramifies upon the smaller vessels throughout the whole internal substance of the organ. The *tissues* to which these smaller nerves are finally distributed are (from the results of my investigations) solely the *walls of the smaller bloodvessels.* The eye, assisted by the lower powers of the microscope, fails in detecting *any branches* (excepting those mentioned) passing into the filaments of the trabecular framework, the pulp tissue, or into or upon the Malpighian bodies. They finally become lost in the coats of these vessels.

ON THE MINUTE STRUCTURE OF THE NERVES OF THE SPLEEN, AND THEIR ULTIMATE DISTRIBUTION.

The minute structure of the trunks of these nerves consists, in the sheep, of *three elementary structures*, 1st, *Gelatinous* (sympathetic) nerve fibres. 2nd, *Tubular* (cerebro-spinal) nerve fibres. 3rd, *Neurilemma.*

1st. The *Gelatinous* fibres form by far the *chief* component of these nerves. They consist of fibres varying in size from the 5000th to the 2000th part of an inch in diameter. They are of a pale colour, and either of homogeneous texture, or faintly granular, or longitudinally striated. Imbedded in their sub-

stance are seen nuclei of varying form and size; the majority are of an elongate oval form, and lie in the long axis of the fibre, their nucleoli being indistinct. Some of the nuclei are round. In some cases they are of the *same* diameter as the fibre itself, and fill up the entire space between its margins. In other cases they are of half the diameter of the fibre, occupying either its centre or margin. These fibres are collected into bundles of varying size, are placed parallel one with another, and are with difficulty separated. By the action of *acetic acid* these fibres are rendered much paler, and more indistinct, but are *not* completely dissolved: the nuclei are darker and more distinct.

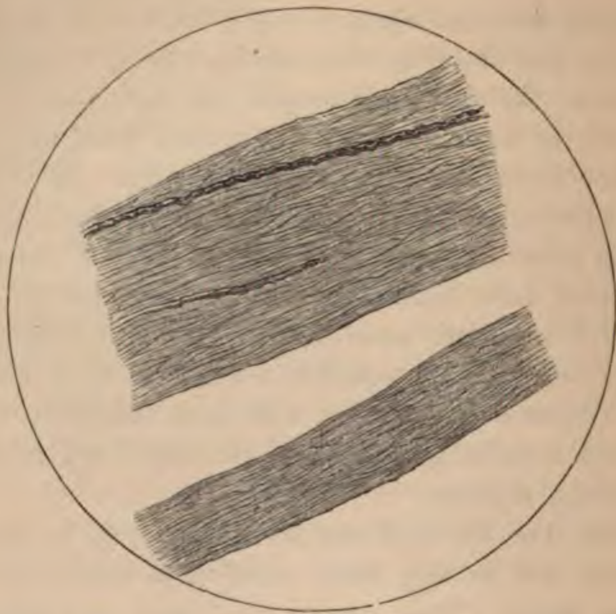
2nd. The *tubular* fibres are also present in these nerves, but in *very small quantity*, as compared to those above. They present the same appearances and structure here as elsewhere. They differ *considerably in size.*

3rd. Numerous *fibrillæ* of *white fibrous tissue*, forming a neurilemma, are also observed in these nerves, uniting together the bundles of fibres, and investing the larger branches.

The structure of the finest ramifications of the nerves varies. In some cases they were composed *entirely* and *solely* of the *gelatinous fibres*, whilst in other cases they were made up chiefly of these fibres, but containing either a single one, or two, or three primitive cerebro-spinal nerve tubules, presenting their normal appearance (Fig. 50).

As regards the *ultimate distribution* and *mode of*

Fig. 50.*



termination of either the tubular or gelatinous fibres composing these nerves, I am unable, after the most careful examination, to afford the least knowledge as to whether the tubular fibres terminate by loops, or whether both kinds terminate by free extremities. It has lately been asserted by Kölliker that 'a division of the *primitive nerve fibres* takes place in the nerves of the spleen,' and that this division occurs in the trunks, as well as 'in the smaller branches in the

* The two drawings in this figure illustrate the structure of the smaller nerves in the interior of the spleen. The upper one consists of a large number of gelatinous fibres, among which are seen two cerebro-spinal nerve tubules. The lower one consists entirely of gelatinous nerve fibres.

interior, but *not* in the *smallest* branches.' I have examined the trunks of the nerves, as well as the smaller branches in the interior of the organ, but in no single instance could I ever detect a division of the primitive nerve fibres; many nerve tubules crossed each other at a certain point, presenting the fallacious appearance of a division having taken place.

The nerves of the spleen in many animals present some very remarkable differences that may be worthy of notice. Thus in the sheep, ox, and horse, they are of very considerable size, whilst in the pig they are almost as small as in man. In the sheep, the diameter of all the trunks taken together equals the diameter of the splenic artery; and in the horse are even larger than the artery, in some cases. Now, this remarkable difference in size does *not* depend on an actual *increase in number* of *nerve tubules*, but on the existence of a large quantity of white fibrous tissue, which invests the nerve and its component tubules; whilst in man and some other animals, as, for instance, the pig, the exact reverse of this occurs.

PART IV.

COMPARATIVE ANATOMY OF THE SPLEEN.

The comparative anatomy of the spleen as a means of elucidating the function of this organ, affords very considerable information. In this section of my subject I shall not only mention the general anatomy of the organ in the several classes, but consider also the minute structure of the several tissues composing it in each. In this way I trust that I may be able to illustrate some very interesting points in the physiology of this organ. For the following description that I am enabled to give from my dissections of many rare animals, I am mainly indebted to the munificence of the Council of the College of Surgeons, who have permitted me to have the freest access to their rich collection of store preparations.

The *most prominent* result of this portion of my investigation tends to prove that the *spleen exists without exception in all the vertebrate animals.*

Table showing the Proportion the Spleen bears to the Entire Body in the various Classes of the Vertebrata.

MAMMALIA.

1 to	256 in the Lemur	Average 1 to 277.
1 to	87 in the Bat	
1 to	264 in the Lion	
1 to	226 in the Fox	
1 to	716 in the Kangaroo	
1 to	211 in the Squirrel	
1 to	256 in the Moschus Moschiferus	
1 to	256 in another specimen of the same	
1 to	226 in the Rat	

BIRDS.

1 to	5040 in the Puffin	Average 1 to 2838.
1 to	4920 in the Oyster Bird	
1 to	3673 in the Ostrich	
1 to	2560 in the Spoonbill	
1 to	2160 in the Owl	
1 to	960 in the Pheasant	
1 to	553 in the Cormorant	
1 to	1324 in the Water-hen	

REPTILIA.

1 to	1364 in the Frog	Average 1 to 1492.
1 to	1589 in the Toad	
1 to	11,150 in the Snake	

FISHES.

1 to	3258 in the Herring	Average 1 to 2131.
1 to	2159 in the Whiting	
1 to	2000 in the Mackerel	
1 to	1638 in the Eel	
1 to	1600 in the Flounder	

MAMMALIA.

1. *Quadrumana.*

In the apes the spleen is not unlike in form to the same organ in the human fœtus, being oblong, and its position similar—being placed on the left side of the stomach, to which it is connected by the usual peritoneal fold. I found, however, that the splenic artery, although presenting a distribution similar to what is found in man, is rather *smaller* than the other branches of the cœliac axis. The splenic vein is of considerable size; its course and distribution are similar to what is seen in the human subject. In the Hocheur monkey (cercopithecus nictitans) its form is triangular, but its position and the arrangement of its vessels offer no peculiarity.

In the *lemurs* I found that the organ presented a widened horse-shoe form, being situated below and to the left of the cardiac end of the stomach, its upper end approximating to that part, the concavity of the organ embracing the left kidney, which is not bound down to the spine, but lies almost loose in the cavity of the abdomen. It is held in its situation by a fold of the great omentum, which is attached to the hilus, and partly by a fold which passes from the cardiac end of the stomach and transverse colon. The artery supplying the spleen, which does not

exceed the hepatic in size, after previously giving off a branch to the stomach, is distributed as in man. The weight of the spleen in proportion to the whole body is as 1 to 256.

2. *Cheiroptera.*

A considerable difference is observed both in the position and *size* of the spleen in the cheiroptera that I have examined; a fact also noticed both by Cuvier and Meckel. Thus, in the *galæopithecus* and in the *pteropus edulis*, both of which belong to the *frugivorous* genera, the organ is of *small size*. In the former it has a triangular form, and is placed on the left side and lower border of the cardiac end of the stomach, being held in its position in the same way as in the lemur; whilst in the latter it is of a narrow oblong form, and is placed transversely across the lower border of the stomach. In the galæopithecus the splenic artery is of *larger* size than either of the other branches derived from the cœliac axis, and is also distributed as in the lemur. In the insectivorous cheiroptera, on the other hand, as the plecotus auritus, the spleen is of large size, being in proportion to the weight of the body as 1 to 87. It is of an elongate, three-sided form, curved upon itself, and placed on the left side of the stomach, to which it is connected by the usual peritoneal fold. Lastly, in the *carnivorous* species, as in the *vespertilio*, I found the spleen of very considerable size, of an elongate oval form, and placed at the lower border

and left side of the stomach. These *differences* in the size of the spleen in allied animals, the habits of which are, however, greatly *dissimilar*, are very highly important aids to our determination of the function of the organ.

3. *Insectivora.*

In the banxring (Tupaia Javanica), whose habits are *partly frugivorous and partly insectivorous*, the spleen is not of large size; it is of a narrow elongate form, curved upon itself, occupying its usual position on the left side and lower border of the stomach. The splenic artery is here *smaller* than either of the other two branches of the cœliac axis, and distributes in its course many branches to the cardiac end of the stomach, which are even *larger* than those distributed to the spleen itself. The splenic vein is double the size of the artery.

In the shrew (sorex), whose habits are *entirely insectivorous*, the organ is of very considerable size, being of an oblong form, occupying a position on the left side of the stomach, and being held in connexion with that organ by a long gastro-splenic ligament, it is connected also with the great omentum, and with the front of the left kidney behind. The splenic artery in this animal equals the size of the hepatic, and is distributed to the spleen in a similar manner with the same vessels in the tupaia, but the branches to the stomach from this vessel are much *fewer* and *smaller* than in that animal.

4. *Carnivora.*

Among the digitigrada, I have dissected the spleen in the polecat (*mustela putorius*), ermine (*mustela erminæa*), otter (*mustela lutra*), in the fox (*vulpes lagophus*), and in the ichneumon (*herpestes pharaonis*). In all, excepting in the last-mentioned animal, the spleen has much the same form and size, and occupies the same position. The organ is of moderate size, and of an elongate form, rounded at one or both ends. In the otter, the upper half is much narrower than the lower one, which is almost twice its breadth, and presents two small prolonged rounded appendages, of small size. In the ichneumon, while it presents the elongate form most usual in the carnivora, it has the singular peculiarity of being completely divided into two lobes, which are connected together through the medium of the peritoneum. In all of these animals the organ occupies a similar position on the left or cardiac end of the stomach, being held in connection with this organ by a gastro-splenic fold, continued below into the great omental fold, with which the lower end of the organ is in all cases connected. The *size*, *course*, and *distribution* of the vessels of the spleen are exactly the same in each of the above-mentioned animals. In all, the splenic artery is by far the largest branch of the cœliac axis, excepting in the ermine, where the hepatic is of *equal* size. In all, too, the distribution is precisely similar, some branches passing to the

spleen and others to the stomach and pancreas; but it is a fact worthy of notice, that in the ichneumon the branches which pass to the substance of the spleen are very much *smaller* than those which pass to the *stomach*, or even to the pancreas. In *all* these animals the splenic vein is of considerable size, being formed in the usual manner, by numerous small vessels, and joins with the mesenteric vein, which it equals in size, to form the portal vein.

Among the *plantigrada* I have dissected the spleen in the coati mundi (*nasua fusca*) and in the bear (*ursus arctos*). In the coati mundi it is of small size, and somewhat rhomboid in form, having the same position and attachments as in the animals above mentioned. In the bear it has the same elongate form that it presents in the carnivora generally. In the felidæ that I have dissected the spleen is of *large* size, much larger than in the other order of the carnivora. In the lion it is of an elongate form; in the leopard of an irregular oblong, with, in both cases, the usual positions and connections. The splenic artery is *by far* the largest of the three branches of the cœliac axis, having a course and distribution similar to what has been found in the other carnivora; but here the singular peculiarity again presents itself that was observed above in the ichneumon—namely, the small size of the branches distributed to the spleen as compared with those passing to the stomach. The splenic vein is, however, considerably larger than the artery.

In the carnivora, the proportion that the spleen

bears to the whole body is as 1 to 264 in the lion, and as 1 to 226 in the fox.

5. *Amphibia.*

In none of the mammalian classes does the spleen present a more perfect adaptation to its function as a reservoir for blood than in the members of this group. It is well known that the *inferior vena cava*, as it passes at the back part of the liver, as well as the hepatic veins themselves, form a voluminous sinus, which is beautifully adapted to effect a reservoir for the blood, which naturally accumulates during the suspension of breathing, as is occasionally the case when these animals pursue their prey beneath the surface of the water. In two specimens of the common seal (*phoca vitulina*) that I have examined, a fœtal and an adult one, the organ in both cases was of *very considerable size*, and, in the adult one, highly lax and *distensile*, its outer surface being thrown into a considerable number of close longitudinal folds of various size, indicative of the amount of dilatibility of the organ. In the adult specimen it was seven inches in length, and two in breadth, but so highly elastic was its structure, that by force it could be extended to almost double its size in both directions. In the fœtal specimen its length was only two inches, its breadth one. In both cases the *under* surface of the organ presented a distinct lobulated arrangement precisely similar to the separated portions of the salivary gland, the

vessels enclosed by their sheaths subdividing and ramifying on the under surface of the organ, through deep furrows in the interspaces, between which the separate subdivisions of the gland may be observed. The organ occupies its usual position on the left side of the stomach, to which it is connected by the usual gastro-splenic fold, which is continued below into the great omentum. The splenic artery supplying the organ is the largest of the three branches of the cœliac axis. Its distribution is similar to that which is usually observed. The *vasa brevia* are *few* and of *small* size. The spleen, also, receives a branch from the gastric artery. The splenic vein is of large size, much larger than the artery.

This hepatic venous reservoir in the liver of the seal, the ready communication, consequently, between these vessels and the portal system, and through the portal system with the spleen, by means of its large afferent vessel, are evidences of the most consummate design in the adaptation of this highly distensile organ, as a partial reservoir for blood during the temporary and occasional obstruction to the circulation.

These facts receive additional confirmation from the results of *experiments* already detailed, where considerable enlargement in the size of the organ, with enormous increase in the amount of blood, were found where respiration, and consequently the circulation, were artificially impeded.

6. *Marsupialia.*

It has been already seen that the size of the spleen is very considerably modified, according to the habits of animals, and according to the kind of nutriment upon which they exist, being of *very considerable size* in the carnivora. The present most interesting family, though essentially different from all others in their organization, yet comprehend genera fed upon every variety of nutriment, some being *herbaceous*, as the kangaroo, others frugivorous, or frugivorous and insectivorous; whilst, lastly, others are carnivorous. I have dissected the spleen in several genera of this group, and in all, excepting the ursine opossum (*dasyurus ursinus*), I have found it of very *small* size. The habits of this animal, as is well known, are extremely voracious, feeding indiscriminately upon raw flesh, carrion, blubber, &c. In this animal the spleen is of very large size.

The other genera of this group that I have dissected are the *phalangista fuliginosa*, the bandicoot (*perameles nasutus*), the kangaroo (*macropus major*), the petaurus scuircus, comprising animals whose habits are herbaceous, frugivorous, or insectivorous.

Although the *size* of the organ differs, as above mentioned, in certain genera, yet its form, position, and connections are much the same in all. The spleen in this family is always very long and exceedingly narrow, and flattened: in the kangaroo it measures eight inches in length. It also, in most

cases, presents the singular peculiarity of its lower end being subdivided into two lobes, of which the upper or more anterior one is long and narrow, the lower one short and somewhat broader. In the bandicoot, however, its anterior end is not bifurcated, but terminates by an irregular rounded margin. It is situated in all the above-mentioned animals on the left side and lower border of the stomach, being held in connection with that organ for the upper half of its extent by the usual gastro-splenic fold; its long, narrow, bifurcated portion is attached to the great omentum, the shorter subdivisions of the organ, which lies free in the abdominal cavity, being held in its position by a fold of peritoneum which arises from the spine behind.

The distribution of the vessels supplying this organ is almost exactly the same in each, but the size of the primary trunks differs in the various genera. In the insectivorous bandicoot, the splenic is the *largest* of the branches of the cœliac axis; in the phalangista, the splenic and hepatic vessels are of *equal* size; whilst in the kangaroo and dasyurus, that vessel is smaller than the hepatic.

The proportion which the spleen bears to the body is, in the kangaroo, as 1 to 716, to the liver as 1 to 8.

7. *Rodentia.*

I have dissected the spleen in numerous species of this very important order of the mammalia, with a view to observe if any difference was to be

found in the condition of the organ among the hybernating species, either during or preceding their torpid condition; if, in fact, the spleen, in any way, could be considered as a reservoir for nutriment during hybernation, as the thymus gland is for nourishment in the service of respiration during the same time.

The results of my investigations would be to entirely negative this opinion. The spleen, in fact, in almost every member of this order, appears, from its exceedingly small size, to be reduced in importance, as compared with many other genera of the mammalia.

In several specimens of the marmot (*mus Alpinus*) that I have examined, the spleen was of *small* size, narrow and elongated in form, situated on the left side of the stomach, to which it was held by the usual gastro-splenic fold.

In the mus coypus, hydromys, the jerboa (*dipus*), the rat (*mus rattus*), the squirrel, three different specimens of which I dissected, the sciurus vulgaris, sciurus niger, and sciurus quadrivittatus, and in the porcupine (*hystrix cristata*), the spleen presents much the same form, being long, thin, narrow, and generally flattened, highly elastic in structure, and placed on the left side and lower border of the stomach. In the hoary marmot (*arctomys*), I found its form somewhat different from the above-mentioned. It is short, somewhat curved upon itself, and of an irregular triangular form, presenting a deep notch at its inner margin, where it is in apposition with the left

kidney, its position with regard to the stomach being still the same. In one of the specimens of the sciuri (*sciurus quadrivittatus*), I observed a small accessory spleen; and, in the hystrix cristata, two in the gastro-splenic fold. The organ is in all cases held in its position with the stomach either by a distinct gastro-splenic fold, or by a fold of the great omentum. I have dissected the bloodvessels of the spleen in the *mus Alpinus*, the *mus coypus*, the *arctomys*, and the *sciurus niger*. In all, as might be expected from the small size of the spleen, the splenic artery is *smaller* than the *hepatic*—in the mus Alpinus, arctomys, and sciurus niger, only equalling in size the gastric artery: their distribution offers no peculiarity. In the hoary marmot the vein is considerably larger than the artery.

8. *Edentata.*

In this interesting family, comprising animals of *very varied* habits of life, considerable difference is seen to exist in the *dimensions* of the spleen, a difference that has been before frequently remarked, in connection with the kind of food, and the simplicity or complexity of the alimentary canal, in certain genera.

In the *sloth* (*bradipus tridactylus*), which is exclusively herbivorous in its habits, and where the stomach and intestinal canal present a more complicated structure, the spleen is *exceedingly small*, its form somewhat of an irregular triangle, the base of which is connected to the stomach by a small and very

narrow gastro-splenic peritoneal fold. The vessels supplying this organ, derived from the cœliac axis, are small as compared with the other genera of this order, and the splenic vein, though larger than the artery, is not of very considerable size.

In the Cape ant-eater (*orycteropus*), and in the great ant-bear (*myrmecophaga jubata*), the former of which is insectivorous, and the latter of both *insectivorous* and *carnivorous* habits, and where in both the stomach and intestinal canal present a less complicated structure, the spleen is of *very considerable size.*

In the *orycteropus* it is of an elongate form, rounded and somewhat broader at its upper extremity than below, and presenting a notch at the lower end which partially divides the organ into two lobes. It is placed in its usual position with the stomach, and connected with it by a fold of peritoneum, which is continued below into the great omentum.

In the *great ant-eater*, the organ is also exceedingly long and narrow, its upper end bifurcating into two long pointed segments, the anterior of which is long and narrow, the posterior one short and terminating by a fine point. Its position and attachments being similar to those of the orycterope. Corresponding with the large size of the organ in this animal, the vessels supplying it are found increased in size, the splenic artery being *equal* to the hepatic; the origin and distribution of the vessel, however, offer no peculiarity.

Lastly, in the *armadillo* (*dasypus*), whose habits are *chiefly* carnivorous, the spleen is of very large size;

it is of an irregular oblong form, not long and narrow as in the *ant-eater*, but short and thick; the organ is deeply divided into two lobes, which are directed obliquely to the right; the upper or anterior lobe is the longer; the lower, which is much thicker and shorter, presents a square notch at its lower margin. It retains its usual position and connections with the stomach.

9. *Monotremata.*

In this most interesting group of the mammalia, the spleen assumes a more singular form than has been observed in any other classes. I have dissected it both in the echidna and also in the ornithorhyncus.

In the *spiny ant-eater* (*echidna*) it consists of three long and exceedingly narrow lobes, which meet together at a central point; each lobe is about an inch and a half in length, the one directed to the left being slightly the shortest of the three; the lower one terminates by a broader and more rounded extremity than the others. It is placed beneath and below the stomach in a fold of the great omentum, the lower branch being attached to a fold of the mesentery which retains the rectum in its position, and occupies the middle line of the body. In the specimen I dissected, the spleen was not of large size; it was exceedingly thin, and its tissue highly elastic. The vessels of the organ are very diminutive; there is no true splenic artery as derived from the cœliac; the only arterial branches it receives are those derived from the gastric artery.

In the *ornithorhyncus*, on the contrary, the spleen is

of very *considerable size*; its form is as peculiar as in the echidna, consisting of three unequal lobes. The largest and longest of these runs from left to right transversely across the abdomen below the stomach, measuring about six inches, being broader towards the left than on the right side, where it terminates in a somewhat pointed extremity; the two other lobes occupy the left extremity of the one described, of which the smaller, about one inch in length, runs upwards by the side of the stomach, the other downwards. The long lobe is held in connection with the stomach by the great omentum, the two others by a fold of the peritoneum, which serves to hold the end of the colon and rectum in the medium line of the body. The splenic arterial branches, which are larger than the hepatic, are derived partly from the cœliac, and partly from the superior mesenteric. Its veins are numerous and large. In the ornithorhyncus, as in the seal, the hepatic vein, as is well known, and the vena cava, at its junction with this vessel, form a large reservoir, adapted to contain a considerable quantity of blood, which naturally accumulates when the circulation is obstructed during suspended respiration, as is occasionally the case when the animal is seeking its prey beneath the surface of the water. Now in these animals, as in the seal, the large size of the spleen, its great distensibility, as well as the large size of its veins (which, through the portal system, communicate directly with the hepatic veins), are admirably adapted to assist as a reservoir for blood during its obstruction under the above-mentioned conditions.

10. *Pachydermata.*

In this order I have dissected the spleen in the *peccary* (*dycoteles*), *the hyrax*, and in the horse (*equus caballus*).

In the *peccary*, it is a long but narrow viscus, the anterior extremity of which is rounded, the posterior one pointed; its position is peculiar, lying beneath the stomach in a transverse direction, to which it is connected by a distinct gastro-splenic fold. It is not of large size, and the vessel which supplies it is small, not equalling the hepatic in size. The distribution of this vessel offers no peculiarity. The vein is *considerably larger* than the artery.

In the *hyrax*, it is also of *small size*, and not unlike in form the same organ in the horse, being flattened and irregularly triangular; its margins presenting an uneven foliated appearance; its upper and posterior border is rounded, the lower and anterior one tapering to a narrow elongate and indented point.

In the *horse* the spleen is of very large, but varying size; it is flattened, and of an elongate triangular form, its broad end being directed backwards, its narrow end forwards; it occupies its usual position on the left side and lower border of the stomach, to which it is connected by the usual gastro-splenic fold. Here also the vein is *considerably larger* (four or five times) than the artery.

11. *Ruminantia.*

The anatomy of the spleen in this very extensive family presents a constant type; but there are many peculiarities in it that are not to be observed in any other animals. It is generally of *large* size, but thin and flattened. In the genus *antelope* it is a large, flattened, roundish organ, situated about the centre of the left side of the stomach, to which it is connected by a fold of peritoneum which passes across it. The splenic artery, which is here larger than the hepatic, is not distributed to the spleen by *many branches*, but enters the organ at its posterior border as a *single* branch without subdivision, a peculiarity not met with in any other order of the mammalia. The splenic vein, which also emerges as a single trunk, is six or eight times the size of the artery. In the *sheep* (*ovis*) a similar arrangement prevails.

In the genus *cervus* the form of the spleen, which is large, is elongate, oval, narrow below; its upper border obtuse and rounded. The position of the organ, however, and the distribution of its vessels are similar to those in the *antelope.*

In the *llama pacos*, it is of an irregular semi-lunar form, thin and flat. Its position and attachments offer no special peculiarity.

In the *moschus moschiferus* it is of an irregular oval form.

12. *Cetacea.*

I have had no opportunity of dissecting the spleen in the *herbivorous* cetacea, as the manate (trichechus manatus) or the dugong (halicore dugong). In an embryo manate six inches long, dissected by Daubenton, the spleen was a single organ, undivided, round, and *very small* in size.

In the *carnivorous cetacea*, I have dissected it in the porpoise (*phocæna communis*) and in the *whale* (*balæna mysticetus*). In the *porpoise* the spleen, instead of existing as a single organ, presents the singular peculiarity of being formed of several separate lobes, all of which, however, occupy a relation either with the first cavity of the stomach or the omentum. The largest, about the size of a large walnut, is placed at the back part of the stomach, near to the pancreas; it is round, and its surface distinctly lobulated, with numerous large veins ramifying on its surface. Two smaller ones are found lying on the surface of the stomach, about the size of large peas, whilst three others of small size, and lying in close proximity with one another, occupy the margin of the great omental fold. The number of these separate lobes appears, from the description of various authors, to be subject to great variety, Cuvier describing seven, Bartholin three, and Hunter two only. Each receives a separate branch of the splenic artery, which is of small size. In the *dolphin* it also

consists of many lobes. In the fœtus of the great northern whale (*balæna mysticetus*) no mention is made of the spleen by Cowper. In one which I dissected, about twelve inches in length, the spleen was a *single* organ, of small size, and of an elongate oval form, placed on the left side and lower border of the stomach, to which it was connected by a short gastro-splenic peritoneal fold. I could not observe any supplementary spleens.

If we contrast the size of the spleen in the amphibia and the cetacea, very great differences are observed between them, although their habits of life do not at first sight appear dissimilar. I have already stated that in the amphibia and other animals of allied habits, the spleen, by its large size and distensile structure, serves as a reservoir for blood, which naturally accumulates in the inferior vena cava and the hepatic reservoir, and, through this channel, in the portal system and spleen, when the venous system is obstructed as a result of suspended respiration. In the cetacea, however, where similar habits prevail, the spleen is of exceedingly *small* size. How is this apparent anomaly to be explained? The peculiarities in the venous system of the seal *are limited* to those that I have already mentioned, and they are admirably adapted to the *occasional* function they are required to perform during the *temporary* suspension of respiration occasioned whilst the animal is diving in pursuit of its prey. The peculiarities of the vascular system in the cetacea, on the contrary, are of a twofold character. In the first place, they are provided with a

complicated arterial plexus in the thoracic region, forming a large reservoir for pure arterial blood, capable of supplying the animal, not only during *an occasional*, but during its *long continued* existence beneath the surface of the water; and, in the second place, the venous system forms far more complicated reservoirs (not confined to certain parts, as in the seal), but diffused through every part of the body, and all of which have intimate and frequent communications one with another, admirably adapted for the considerable accumulations of blood that must occur during the *very long and continued* suspension of breathing during their existence beneath the surface of the water. These complicated diffused venous reservoirs, I believe, answer the end in the cetacea, during their *long continued* suspension of the respiratory act, that the hepatic reservoir and the large and highly distensile spleen serve in the amphibia during their *occasional* and *periodic* suspension of the same act. If in the former animals this reservoir function had devolved upon the hepatic sinuses and spleen, as in the amphibia, they would have been of a size out of all proportion to the rest of the body. Hence the small size of the organ in the cetacea.

The chief results observed in these investigations are: The large size of the spleen in all the members of this class as compared with the other vertebrata. This is seen by comparing the tables illustrating the relative proportion which the organ bears to the entire body in each, presenting its maximum of development in this class, in connection with the greater

general completeness and requirements of their organization. Amongst these the spleen has a much larger proportional size in the carnivora and insectivora than in the remaining orders. It is consequently largest where the intestinal canal presents (as in the above-mentioned genera) the least complex structure, where digestion is most rapidly performed, and consequently where the new material is more suddenly added to the blood. Lastly, in the amphibia, its large size and its peculiarly lax and distensile texture are in perfect harmony with the requirements of the animals of this class, being peculiarly adapted as a reservoir for the blood which accumulates in the venous system during the suspension of respiration.

MINUTE STRUCTURE OF THE SPLEEN IN THE MAMMALIA.

The *external fibrous tunic* in the mammalia is generally thicker and *more highly elastic* than in man. This is more especially the case in the seal, pig, ox, and sheep; at the same time also its serous covering can be more easily removed as a separate lamina. In correspondence with this first-mentioned peculiarity, as might be expected, the elastic fibres of this tunic exist in greater quantity, and are much stronger and thicker than in the human subject. In addition to the elements already mentioned as composing this tissue, muscular fibre cells may be detected in this tunic, in the dog, cat, pig, and ass. The *trabecular tissue* presents the same general characters that have

been already described, although the size of the fibres and the form of the spaces left by their junction differ in certain genera.

In the *carnivora* the fibres and meshes are numerous and of very small size. In the *ruminantia* an arrangement exactly opposite to this is observed, whilst in the horse the fibres are thick and solid, and the meshes of small size. Their structure also is similar to that of the investing tunic, the elastic fibres being thicker, stronger, and more numerous than in man. Muscular fibre cells are also found composing part of their structure in most of the genera of the mammalia.

The *Malpighian bodies* have a similar arrangement, and present precisely the same structure as in man. They differ, however, in size in certain genera, being large in the *ruminantia* and *rodentia*. The structure and arrangement of their contents, their chemical composition, and the laws which regulate their extreme variations in size, appear to be precisely similar, as far as I have been able to ascertain, to what I have already mentioned.

The *pulp* of the spleen in mammalia presents the same characters, in most respects, that I have already described, consisting of a granular plasma, nuclei, and nucleated vesicles in every process of development, growth, and decay. It also contains, in all cases, a large quantity of *normal* blood corpuscles. It is *very rarely*, however, that any of these can be observed to be included in cells. I have *most frequently* observed them in the horse, where they occur in very con-

siderable quantity, and with great distinctness. In the rabbit and rat, as well as in the other mammalia, I have only seen them occasionally, and in small numbers.

With regard to the *bloodvessels* and the *blood* of the spleen in this class, I have no special observations to offer beyond what I have already mentioned.

AVES.

In numerous dissections that I have made of the spleen in birds, I have not found that its general anatomy differs to such a degree (except in that of form) in any of the various classes as to warrant a separate description of the organ in each class. The description that I shall now give will apply to all; at the same time I shall mention any individual peculiarity that may be worthy of notice.

The spleen of birds is generally of small size as compared with the body, much smaller than in the mammalia, as is seen from the accompanying table. (See p. 273.) Its form is usually somewhat spherical, as in the cormorant (*phalacrocorax gracilis*) the owl, the puffin (*mormon fratercula*), the oyster bird (*hæmatopus ostralegus*), the spoonbill (*platalea leucorodia*), and some others. In the Virginian owl (*bubo Virginianus*) it is conical, and in the ostrich (*rhæa Americana*) and moor-hen (*gallinula chloropus*) cylindrical. Its size, though small, is subject to great variation in certain classes. I have found it *largest* in the rapacious cormorant, an interesting circum-

stance in connection with its large size; in the mammalian carnivora; it is also large in the diving moorhen. It occupies a similar position in all classes, being placed at the back part of the proventriculus, immediately above the stomach, and being held in its position by a delicate peritoneal fold. Corresponding with this diminution in the size of the spleen, its blood-vessels become considerably reduced in importance, and instead of forming one of the chief branches of the cœliac axis, they are derived entirely from one of the *branches* of that vessel (the gastric), previous to its distribution to the stomach, liver, duodenum, and pancreas. The *splenic vein* also is not, as in the mammalia, one of the *main* trunks of the vena portæ, but consists merely of three or four *small branches*, which open into the gastric, the vena portæ being formed by the junction of this vessel and the mesenteric vein. In the *water hen* it consists of a *single* long trunk, which is larger than the smaller branches combined in other birds. This peculiarity in connexion with the somewhat larger proportional size of the spleen may have some relation to the peculiar habits of the animal, which involve a considerable retardation to the blood during its impeded respiration under certain circumstances.

MINUTE STRUCTURE OF THE SPLEEN IN BIRDS.

The most external investing membrane is thin, almost transparent, of a greyish colour, somewhat elastic, and only loosely attached to the structures

beneath, its inner surface giving off numerous but somewhat delicate trabeculæ. It is composed of innumerable delicate fibrillæ of white fibrous tissue,

Fig. 51.*

collected into bands, which cross each other in various directions. Most of these fibres have no nuclei, presenting a wavy and somewhat tortuous

* The splenic corpuscles from the spleen of the common fowl, showing their form and situation.

course; a few are spindle-shaped, presenting a nucleus in their centre, which either becomes elongated at both ends, or else the cell wall is so disposed. On the application of acetic acid myriads of small dark oval-shaped nuclei are observed, as well as an exceedingly dense mesh, formed by the interlacing of the fibres of the *finer* variety of elastic tissue. They are remarkable for their number, their exceeding delicacy, and frequency of their peculiar curlings. The *trabeculæ* are not very numerous; they are delicate white fibrous cords or bands, which arise both from the inner surface of the investing membrane and from the sheaths of the vessels reflected in from the outer tunic. These, joining together, form meshes, in which the pulp tissue and Malpighian corpuscles are lodged. They are composed of fine delicate wavy fibres, of white fibrous tissue, and spindle-shaped fibres with an elongated rod-like nucleus, the margins of which are highly refractive and dark, apparently solid, and containing no nucleolus. There are also many of the finer variety of the curly elastic fibres.

The Malpighian corpuscles (fig. 51) in birds are very numerous; they may be seen as minute greyish white points, situated in and surrounded by the red spleen substance. It is exceedingly difficult to state their exact number in the entire organ, but so *thickly* are they strewed throughout its substance, that they give to its section a reddish *grey* appearance. Their size varies very considerably; the largest have a diameter about the 100th part of an inch, some the 160th, 190th, 180th, 250th, 333rd, 666th, the latter being

the smallest; their shape is spherical; they are situated either on the sides of the smaller vessels, or more frequently at their angle of bifurcation, rarely being connected to the vessels themselves by a pedicle. The vessels do not apparently traverse the substance of

FIG. 52.*

these bodies. These corpuscles (fig. 52) are composed of a fine and exquisitely delicate membrane, which is transparent, homogeneous in texture, presenting in some cases an exceedingly fine dark granular texture. This membrane does not present the same appear-

* One of the splenic corpuscles from the slpeen of the fowl, shewing its external capsule, and the nuclei contained in its interior.

ances as in the mammalia, and is not apparently formed from the sheaths of the vessel to which they are intimately adherent, for the fibrillated structure of the sheath is very manifest, whilst it is not present in the membrane of the Malpighian vesicles. An exceedingly delicate capillary net ramifies on the outer surface of each body.

CONTENTS OF THE MALPIGHIAN VESICLES.

The contents of the Malpighian vesicles in birds are of three kinds. First, granular matter; second, nuclei; third, nucleated vesicles.

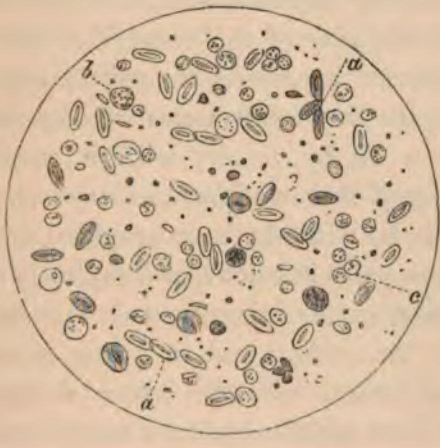
1st. The granular matter exists in rather large quantity, but less in comparison with the nuclei; it consists of numerous very minute, but variously sized and chiefly spherical-shaped pale granules, in which are scattered a few minute dark and highly refractive particles like fat granules. These exist, however, in very small number.

2nd. The nuclei are pale in colour, vary considerably in their size; their form chiefly circular, or irregularly circular, consisting externally of a slightly dark margin, and contain in their interior a varied number of small pale granules, generally three or four.

3rd. Nucleated vesicles very rarely exist as forming part of the contents of the Malpighian vesicles. They occur occasionally very sparingly, and consist of an external membrane, containing on its wall a circular nucleus, with one or two distinct circular nucleoli, the cavity of the vesicle containing a few variously-shaped granules.

The same *variation* in the *size* of these bodies, as dependent upon the state of nutrition or the period of digestion of the animal, is also to be observed in birds, and they appear to be regulated by the same general law, as regards such variation, which has already been remarked in the mammalia.

FIG. 53.*



The pulp of the spleen in birds (fig. 53) is composed chiefly of *nuclei*, varying in size, and of an irregular circular form. They present an external dark margin, the interior structure being of a pale granular texture. In some these granules were few in number, darker, and more distinct. Many of these nuclei were surrounded by a faintly delicate cell wall, in the cavity of which may occasionally be seen a few dark granular

* The elements composing the pulp of the spleen in the greenfinch: *a a.* Blood corpuscles; *b b.* Coloured granules contained in cells; *c c.* Dotted nuclei.

particles, or the vesicle may be crowded with granules, rendering the nucleus indistinct.

In the pulp of the spleen in birds may also be observed, *as clearly* as in some of the mammalia, the most interesting metamorphoses of the blood corpuscles. Some of these corpuscles presented their usual normal appearances, others were collected into heaps of varying form and size, in which the *normal* form of the majority of the corpuscles was retained. Many, however, presented numerous characteristic differences; the single corpuscles were of *smaller size*, presenting a *darker colour*, with a *wrinkling and crumpling up of their margins and surfaces.* In some cases corpuscles with similar corrugated margins and surfaces were paler in colour, or completely colourless. Whilst, lastly, some of the corpuscles presented their *usual form*, the nucleus and investing capsule of the disc being intact, but the *colour* wanting. The amount of corrugation which the margin and surfaces of the corpuscles present varies considerably. In some the edge of the disc is merely bent in or wrinkled, whilst in others, the extent of corrugation has been so considerable as to form a small body, the indented and irregular surface of which presents no similarity with the normal blood corpuscle. These appearances I have observed in *every* instance in which the pulp tissue has been examined.

In *one* examination that I made in the common greenfinch, I observed a few separate blood discs, contained in an irregular shaped mass of plasma; they were of a *circular* form, rather smaller than the normal discs, and of a darker red colour. Very nume-

rous vesicles were also seen, of a circular form, and consisting of a delicate transparent membrane, containing in their interior a variable number (one to ten) of irregularly circular-shaped reddish-coloured corpuscles, like blood discs; others contained many variously formed and sized dark granules. In a few cases I have seen in the spleen of birds a number of small elongate, rod-like *crystalline* bodies, of a pale reddish colour; these either presented a perfectly straight form or were somewhat curved; they existed either free or were contained in unchanged or partly changed blood corpuscles.

The result of this examination shows that in the class of birds, although the spleen is, from its smaller size, considerably reduced in importance, yet that the structure of the organ is essentially the same as in the mammalia.

The bloodvessels in the interior of the spleen in birds appear to have an arrangement similar to what has been observed in the mammalia. The veins, which are of extreme delicacy, ramify in an arborescent matter, both on the surface and also in the interior of the organ.

The splenic venous blood contained:

1st. *Normal* blood corpuscles, nucleated, and of a pale reddish colour;

2nd. Blood discs of diminished size, dark edged, with wrinkled and indented margins; some are of smaller size, *pale* in colour, with no nucleus, and irregular serrated margins;

3rd. Small circular-shaped *deep yellow* corpuscles, with dark highly refractive margins.

REPTILIA.

As we descend the scale of the vertebrate series, the function of the spleen appears to be considerably reduced in importance, as shown by the extreme diminution in its size, a diminution more marked in some of the orders of this class than in any other of the vertebrata. And these facts are highly important, as they clearly show what experiment on the higher animals has confirmed—namely, that the spleen is an organ not absolutely necessary for the perfect performance of the functions of life, but that it is an organ superadded, and existing of large size, in the more highly organized vertebrata, where its function is brought into play to *balance* and *regulate* the ever varying conditions of the *vascular* and *nutritive* systems.

Chelonia.

In this order of the reptilia the spleen, which is rounded, with somewhat flattened sides, is larger than in the remaining. Instead of being placed in close proximity with the stomach, as in birds and mammalia, it is firmly bound to the commencement of the transverse arch of the colon, and is about half concealed in a blind sac, formed in a fold of peritoneum, which connects the colon below with the stomach and duodenum above. I have found this arrangement both in the testudo Europœa and in the testudo mydas. In one case I noticed two small

supplementary spleens in the same fold, one about the size of a filbert and the other about half as large as a pea. The bloodvessels supplying the organ present a considerable difference in their size; in the turtle the vein being at least *ten times* larger in diameter than the artery. The latter vessel, which is of very small size, is derived from a trunk given off from the right aorta, and which first supplies the stomach and liver by separate branches, and after supplying the spleen, is finally distributed to the pancreas, duodenum, and remaining portion of the intestines, the branch to the spleen being the smallest vessel of all. Its distribution in the interior of the organ appears similar to what has been seen in the mammalia (fig. 54). The veins, which are *numerous* and

Fig. 54.*

* Venous plexus on the surface of the spleen in the turtle.

of *considerable size*, especially in the turtle, form a dense plexiform mesh, both on *the surface* and also in the interior of the organ, the larger branches having an arborescent arrangement, the smaller trunks *anastomosing* very freely with one another. They do not form, however, one of the main trunks of the portal system.

Sauria.

1. *Emydosauria.* In this family of the saurian reptiles, I have dissected the spleen in the young crocodile and alligator. In the *crocodile* (crocodilus biporcatus) it is of larger size than in many other reptilia, of an elongate oval form, being placed behind the stomach, at the back part of the abdomen, on the left side of the median line, and lying in the fold of peritoneum, which connects the duodenum to the spine. The bloodvessels supplying the organ are by far the *smallest* branches derived from the trunk corresponding to the *cœliac*, and which also supplies the liver, stomach, and part of the intestinal canal. The splenic vein terminates, as in birds, in the gastric, not forming one of the principal portal trunks. In the *alligator* the organ has much the same form and connections, and the distribution of its vessels is similar to those in the crocodile.

2. *Sauria.* Among the *sauria* I have dissected the organ in several specimens of the *lacerta*, *lacerta gecko*, *lacerta calotes*, and *lacerta chameleo*.

In the *gecko* and in the *lacerta calotes*, the spleen is of an elongate oval form; in the common lizard it is

irregularly lobed, and in the chameleon it is round, and of exceedingly small size. In all, excepting in the gecko, it occupies its usual position, being placed on the left side of the stomach, to which it is connected by a delicate peritoneal fold; in the gecko it occupies a position on the left side of the commencement of the intestine. The extreme diminution in the size of the spleen in this order is accompanied with a decrease in the size of the vessels, which are very diminutive. In all of the above-mentioned animals, excepting the chameleon, the nutrient vessel is derived from a trunk given off from the aorta, which also supplies the stomach and the remaining portion of the intestinal canal, the splenic being by far the smallest branch of all. In the chameleon this small vessel is given off from the *gastric artery*, which, in this instance, is derived directly from the aorta.

Ophidia.

The most extreme differences of opinion appear to exist with regard to the *presence* or *absence* of the spleen in this class, Cuvier asserting its existence to be constant in all the members of this group, whilst Meckel, on the other hand, totally denies that any organ exists in the ophidia, analogous to the spleen of mammals. Such great diversity of opinion among authorities so high, led me to adopt the greatest caution in examining the truth of one or the other of these statements, and it is only after the most scrupulous and careful investigation, assisted

by the unerring test of the microscope, that I am enabled to confirm with *absolute certainty* the above opinion of Cuvier, that the spleen does exist in the present class. I have dissected this organ in two specimens of the *boa*, in the *hydrus*, *coluber natrix*, *viper* (*vipera communis*), the *common ringed snake* (*natrix torquata*), and in the *typhlops*, *amphisbæna*, and *anguis fragilis*, where the spleen presents in all a somewhat analogous form. The organ is very small, bearing a proportion to the whole as 1 to 11,150, hardly exceeding in the large boa the size *of a pea*. Its form is irregularly circular, and its surface somewhat lobulated; it is placed on the left side of the pylorus, just at the commencement of the intestine, being partly retained in its position by its attachment to the mesenteric peritoneal fold, and also by its intimate connection with the pancreas, immediately above which it is placed. I have no doubt that it is the close connection this organ has with the pancreas that has given rise to the differences of opinion as regards its existence. The vessel which supplies the organ is of very diminutive size, and is derived from the gastric artery. The veins (fig. 55), which consist of several small branches, unite to form a small vessel, which empties itself into the mesenteric vein; these vessels, before passing from the organ, form a delicate *plexus* on its outer surface, immediately beneath its external tunic, as in the chelonia.

In the *typhlops* the spleen is of minute size, and of an elongate oval form, being situated at the back part, and *right* side of the pyloric end of the stomach, in

the mesenteric peritoneal fold, and above the pancreas, which is of considerable size. In the *amphisbæna* the organ scarcely exceeds the size of a small pea; its

Fig. 55.*

form is irregularly rounded, being placed on the right side of the pyloric end of the stomach, where this organ forms a distinct curve just as it joins the intestine. It is surrounded by a long-tailed prolongation of the pancreas, which is curved partially around it. In the *anguis fragilis* the spleen is about the size of a large pea, placed above the pancreas, on the right side of the pyloric end of the stomach.

It has been already seen that in those mammalia which present a simple stomach and intestinal canal, and where digestion is consequently most vigorously performed, as in the carnivora, the spleen is large, and there appears to be every probable reason that

* Venous plexus on the surface of the spleen in the snake.

its size is in accordance with this function, being large, to regulate the varying conditions of the circulation, which must be very materially modified by a *rapid conversion* of food into blood. If such be the case, it appears at *first sight* remarkable that in the ophidia, essentially carnivorous in their habits, and possessing a voracity greater than other animals, the spleen should be *reduced* in size to the smallest possible proportions, so small, indeed, that its function must be considered to be all but useless. This apparent anomaly is soon explained, when we consider the rate of the digestive action in the latter class as compared with the former. In the carnivora the rapid digestion of the food does not extend over more than a few hours. In that time a very considerable quantity of new material is added *suddenly* to the circulation. But in the ophidia the food, although its nature is the same, is not as *rapidly* digested, this process extending over days, or even weeks, so that the new material is added *slowly and gradually* to the vascular system. I believe that it is this circumstance that will partly serve to explain why this organ is reduced to its minimum of development, and consequently of function, in this class.

Batrachia.

The spleen in this order of the reptilia is of small size, bearing a proportion to the entire body as 1 to 1364. In the *toad* (*rana bufo*) it is about the size of a large pea, of circular form, being

placed behind the stomach in the mesenteric peritoneal fold which connects the small intestine, three or four inches from the pylorus, with the spine, and close to the distal end of the pancreas. Corresponding with the small size of the spleen in this order, the size of the nutrient vessels becomes much diminished, being the smallest of the three principal branches (hepatic and gastric) derived from the trunk analogous to the axis. This branch enters the substance of the gland at its upper part, ramifying in its interior. The veins of the spleen present an arrangement analogous to that usually met with, forming arborescent branchings through the substance and also on the surface of the gland, but not forming a plexiform network, as in the *ophidia* and *chelonia*,—a most interesting fact in connection with the peculiarities presented by the minute structure of the organ in each of these classes.

In the *frog* (*rana esculenta*) the structure of the organ is similar to that met with in the *toad*.

In the *salamander* the spleen is not of very large size; it has an elongate form, and is placed on the left side of the stomach, to which it is connected by the usual peritoneal fold, in which its vessels (branches of the gastric) run. In the *triton* the form, position, and structure of the organ is similar to what was found in the salamander.

Among the *perennibranchiate amphibia*, I have dissected the spleen in the *axolotl*, the *siren*, and *proteus*. In the former animal, although the branchial tufts remain persistent, unquestionably pulmonic respira-

tion is that chiefly exercised. Here the spleen is small in comparison with the size of the animal, whilst in the *siren* and *proteus*, where this arrangement is exactly reversed, where the pulmonic respiratory apparatus has diminished, and that for aquatic respiration has become more perfect, the spleen presents a larger proportional size.

In the *siren* the spleen, which is of large size, is an exceedingly long and narrow viscus, placed in its usual position on the left side of the stomach and intestines, being held in its position by the common mesenteric peritoneal fold. Its length is seven inches; it is exceedingly narrow, and somewhat triangular in form. The artery supplying the organ is not of great size, but the veins are numerous and large, and empty themselves into the long mesenteric vein, which runs along the whole length of the inner side of the organ, terminating above in the vena portæ.

In the *proteus* the organ is also long and slender, rounded above and tapering to a point below; it occupies its usual position on the left side of the stomach.

MINUTE STRUCTURE OF THE SPLEEN IN REPTILIA.

The minute anatomy of the spleen in this class affords many very highly interesting facts in the elucidation of the physiology of this important organ. I have examined its structure in the *chelonia*, the *ophidia*, and in the *batrachian* reptiles. Among the sauria the extreme difficulty of obtaining perfectly recent speci-

mens has prevented me extending my investigations on the minute structure of the spleen in this class. The various elementary structures composing the spleen in this section of the vertebrata are almost precisely similar to what are found amongst the mammalia and birds, consisting of an external capsule and trabecular network, the pulp tissue, bloodvessels, and blood. The Malpighian bodies, which form so important an element in the composition of the organ in the other classes, cannot here be said to exist. Müller detected them in the chelonia, and Oesterlen in the naked amphibia (frogs and toads). In my investigations I have not been able to discover the existence of these bodies in any of the subdivisions of this class.

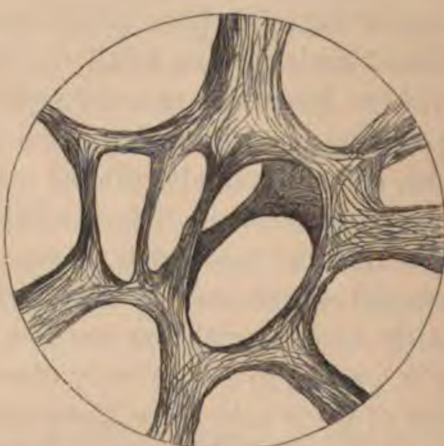
The external tunic consists, in all the members of this order, of two layers—an external peritoneal coat, consisting of oval or circular-shaped nucleated epithelial scales, and an internal or fibrous coat. In the *chelonia* and *batrachian* reptiles this fibrous coat consists of a thin and moderately transparent membrane, composed of numerous minute fibrillæ, which are intimately blended with one another, the fibres composing it passing in almost every direction. On the addition of acetic acid these fibres are partially dissolved, and there are then observed two distinct forms of nuclei. One of these forms consists of minute circular or oval-shaped nuclei, both with and without nucleoli. The other form consists of oblong shaped nuclei; they are pale, and are not contained in separate fibres, but in a pale, finely-granular membrane; they are elongate, club-shaped nuclei, either

straight or variously curved, presenting an outer margin, but containing no nucleoli, and not unlike the nuclei of involuntary muscular fibre. A few fine curling elastic fibres may also be observed disseminated throughout the substance of this tunic.

The *trabeculæ*, which are numerous and large in the chelonia, intersect the substance of the organ in every direction. Their structure resembles in every respect that of the external tunic.

In the *ophidia* the *structure* of the external capsule (fig. 56) and trabeculæ is in exact conformity with the

FIG. 56.*



requirements of the functions of the organ in this class, consisting simply of a complex interlacement of the fibres of white fibrous tissue, no *elastic* or muscular

* A portion of the trabecular tissue in the spleen of the viper, in which no elastic fibres can be detected.

fibres being present. The capsule is exceedingly thick, and sends *numerous very thick* prolongations into the substance of the organ, forming septa or spaces, chiefly of an oval or circular form, in which the proper substance of the organ is contained. Before proceeding to describe the structure that the pulp tissue presents in this class, let me again revert to the differences that are observed in the arrangement of the bloodvessels, and more particularly the veins, in the several subdivisions of this order. In the *chelonia* and *ophidia* both the arteries and veins form a distinct net-like *plexus*, both on the surface and also in the interior of the organ, which is easily demonstrable by an ordinary injection. In the *batrachia*, on the contrary, *no such plexus* can in *any way* be demonstrated. The veins commence both on the surface and also in the interior of the organ, as in the mammalia, by large arborescent branches, which *do not* communicate with one another, excepting by fine channels in the substance of the pulp, the walls of which are simply composed of delicate epithelial scales; consequently, on the introduction of the finest injection, extravasation takes place immediately that it is driven beyond a certain point, although not the slightest amount of force is used. I have reverted to these very interesting differences in the vascular system, as the structure of the pulp and the changes that the blood is observed to be undergoing in this tissue differ very materially in each, a difference that can easily be accounted for, and which is dependent, I believe, upon these peculiarities.

In the *chelonia* and *ophidia*, in which the above *plexiform* arrangement of the bloodvessels exists, I have *never* been able, after the most careful and repeated examinations, to detect *any trace* of the disintegration of the blood corpuscles, either singly or in cells, in the substance of the pulp. The bloodvessels form a *closed* and *continuous* plexus, consequently the existence of the blood corpuscles in the pulp, and their consequent disintegration, *cannot* be effected. The chief mass of this substance is composed of nuclei (fig. 57), of a circular, or irregular

FIG. 57.*

circular form, of varying size, containing in their interior two or three small dark corpuscles, and these form by far the greatest proportion of the substance

* The pulp of the spleen in the snake: *a a.* Blood corpuscles; *b b.* Dotted nuclei; *c c.* Nucleated vesicles; *d.* Vesicle containing granules.

of the organ. Other nuclei may be observed, but few in number, surrounded by a faintly delicate external envelope, of a spherical form; in some of these a few granules may be seen, whilst in others the whole cavity of the vesicle is completely distended with fine dark granules, and the nucleus becomes broken up and disintegrated; lastly, these vesicles may be observed to have burst, and their contents become effused among the elements of the pulp.

FIG. 58.*

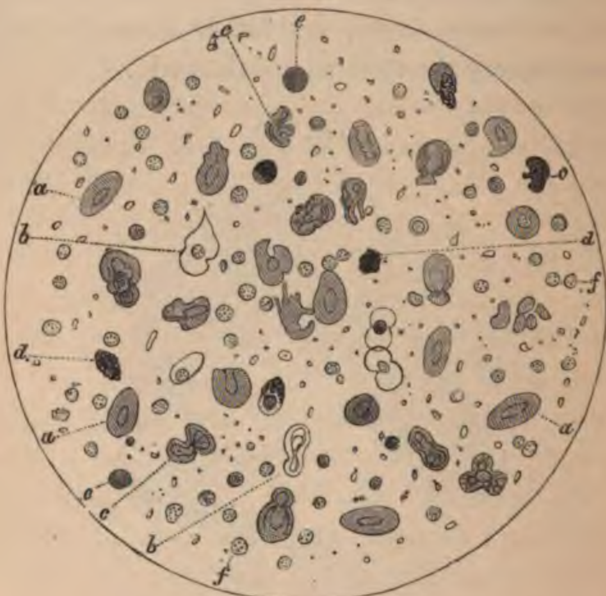
In the *ophidia* the above-mentioned elements are collected into irregular-shaped masses, which are lodged in the interspaces left by the interlacing of the trabeculæ, and the surface of which is in close contact with a delicate capillary plexus.

In the *chelonia* a few dark spherical-shaped cor-

* Blood from the heart of the common frog (*rana esculenta*) as a comparison with next figure.

puscles may be seen, rather larger than the nuclei, and consisting of a mass of small dark and highly refractive granules, contained in a delicate envelope. There may also be seen small coloured granular masses disseminated throughout the substance of the

FIG. 59*



pulp, and existing either as separate reddish brown granules, or these coloured granules are collected into masses, which vary in form and size; their colour

* A portion of the pulp of the spleen in the frog: *a a.* Normal blood corpuscles; *b b.* Blood corpuscles deprived of their hæmatin; *c c.* Blood corpuscles wrinkled and partially disintegrated; *d d.* Blood corpuscles converted into a mass of dark reddish brown particles; *e e.* Vesicles containing a reddish yellow colouring matter; *f f.* Dotted nuclei.

also varies from a bright red to a dark reddsh brown or black; more rarely they may be seen contained in a delicate cellular envelope. This description will suffice to prove the *exact analogy* that exists in the structure of the pulp in the present class and in birds and mammalia, excepting as regards the disintegration of the blood corpuscles.

In the *batrachia*, as the frog and toad, where a plexiform arrangement of the vessels does *not* exist, and where the smaller venous capillaries are found as interspaces in the substance of the pulp, the most remarkable changes may be noticed in the large amount of blood corpuscles effused in its substance; these changes being the more clearly traced in these animals from the considerable size of their blood corpuscles (figs. 58 and 59). Some of the blood discs present their usual form, size, and colour, containing in their interior a small circular-shaped granular nucleus. Others are observed of *smaller size*, of *darker colour*, and having a *circular* instead of an oval form. The margins of these present a wrinkled corrugated appearance, the nucleus either remaining at first unchanged, or else losing its granular form, and becoming more pellucid. This wrinkling or crumpling up of the blood corpuscle is not confined to the margin, but extends throughout its substance, altering the normal form of the blood disc to such an extent as not to be readily recognised until the above-mentioned stages have been observed. This wrinkling and corrugation proceeds until the corpuscle becomes an irregular dark red, or reddish brown jagged mass,

the substance of which has become changed into a coloured pigment granule. In the interior of some of the blood discs which are devoid of nuclei, may be seen three or four minute brilliant reddish granules of hæmatin, which sometimes assume a rod-like form. Similar reddish brown or black granules, but of larger size, which exist either singly or collected into large masses, are also seen to be disseminated through the substance of the pulp. In no single instance, in at least fifty examinations that I have made, examining the organ in every possible variety as regards nutrition, have I ever been able to observe the existence of the disintegration of the blood corpuscles in cells, as described by Kölliker.

Splenic Venous Blood. The emerging blood of the spleen in the frog contains a rather larger number of the white corpuscles than arterial blood; in some occasional cases, also, a few dark red or black pigment granules may be observed. In this respect this blood presents the same peculiarities observed in the emerging blood of this organ in the higher vertebrate animals.

With the exception of a very extreme diminution in the size, and consequently the activity of the spleen in this class, its structure presents much the same characters that have been already observed in the mammalia. The most prominent structural difference is the absence of the Malpighian bodies, which form so important an element of the spleen in the mammalia and birds. It has been seen, from experiments already detailed, that the probable office

of these bodies is to serve as storehouses for albuminous materials when the vascular system becomes charged with a highly nutritious fluid, and that under certain circumstances their contents are discharged, and enter the circulation during an occasional or temporary absence of food; in fact, they form a quickly available sinking fund for nourishment, the elements of which are as rapidly restored again to the circulation as occasion requires. In the mammalia and birds, where extreme hunger is soon followed by fatal consequences, these bodies are found to arrive at their maximum of development, but presenting every variation in size, as caused by differences in the nutrition of the animal. On the contrary, in reptiles, their absence is probably associated with the power that all these animals possess of enduring long fasting with the utmost impunity; their existence is consequently unnecessary.

PISCES.

The spleen in fishes is universally present, but its small size, in proportion to the body, shows that it is an organ of less functional importance than in the mammalia.

In the *osseous fishes*, I have dissected it in the carp (*cyprinus*), whiting (*merlangus*), flounder (*platessa flesus*), herring (*clupea harengus*), mackerel (*scomber*), eel (*anguilla*), cod (*gadus*), pike (*esox lucius*), salmon (*salmo*), bream (*brama*), tench (*tinca chrysitis*), perch (*perca fluviatilis*), and roach. And

in the *cartilaginous fishes*, in the dogfish (*scyllium*), basking shark (*selache maxima*), and lepidosiren. In the lamprey (*petromyzon*), the existence of the organ is questionable; it certainly does not occupy the position in which it is found in all other fishes. In the lancelet the organ is unquestionably wanting.

The proportion that the weight of the spleen bears to the body is in the herring as 1 to 3258; in the whiting as 1 to 2159; in the mackerel as 1 to 2000; in the eel as 1 to 1638; and in the flounder as 1 to 1600. The results of these proportional weights not only serve to show, as above stated, the diminished functional importance of this gland, but a proportional weight about equal to what the same gland possesses in reptiles and birds, and which is, as we have already seen, considerably less than in the mammalia.

The position of the organ is similar in nearly all the various families, being placed either in apposition with the side of the stomach, or with some part of the intestinal canal, by means of a fold of the mesentery. In some few, as in the tench, it is in intimate connexion with the left lobe of the liver — its veins emptying themselves directly into the vena portæ, just at its entrance into this organ. The form of the organ also differs very considerably; most commonly it is, as in the cod, of an elongate triangular form. In the whiting it is flattened and circular. In the flounder, oval. In the skate it is rounded and somewhat flattened, its surface being divided into a number of separate lobules, and among all the highly-organized *plagiostomes*, as in the basking shark, the organ is

subdivided into numerous distinct lobules. The organ is usually single, but in the sturgeon there is an accessory spleen.

In the *lepidosiren* the existence of this organ has been denied by all those who have specially investigated the structure of this animal. In two specimens, however, which I had an opportunity of examining, I discovered the existence of an organ, the relation of which both to the liver, the alimentary canal, and the pancreas, as well as the structure which the organ presented on microscopic examination, would lead me to consider it as the spleen. This organ is of an elongate oval form, situated between the lower part of the œsophagus and the left side of the liver, and about equals the pancreas (recently discovered by Mr. Quekett) in size. It extends from the pylorus below, for the extent of an inch on the side of the œsophagus, and is closely embraced by a delicate peritoneal fold, its lower end approximates to the pancreas, which is placed above and at the back part of the pyloric aperture of the stomach. On the side in apposition with the liver, a large vein passes from it to empty itself directly into the portal vein. Its texture is soft and friable, and, as in fishes, presents a dark brownish speckled appearance throughout its entire mass. Confirmatory microscopic evidence serves to establish this supposition; for, disseminated throughout its entire substance may clearly be seen those large masses of variously-coloured corpuscles, one of the characteristic and main constituents of the splenic pulp to be presently described in fishes.

In the *lamprey* (*petromyzon*), the organ that may be considered as analogous to the spleen, does not occupy the same position as in other fishes, but is placed along the spine, for nearly the whole length of the abdominal cavity. It consists of an elongated spongy mass, composed of a dense venous plexus, which receives the blood from the genito-urinary organs, and also from part of the intestinal tube, communicating with the inferior vena cava by numerous small apertures. Although the absence in its structure both of the elements of the pulp tissue, as well as the Malpighian bodies, might at first sight lead to the inference of its not being a spleen, still, the large size and highly distensile character of this venous structure, so admirably calculated for regulating the varied conditions of the vascular system, as well as its connexion with the bloodvessels of the intestinal tube, are, I think, important proofs of the organ being analogous to the spleen of fishes and the higher vertebrata. In two careful dissections which I made of the *lancelet*, the most lowly organized of the vertebrata, the spleen was not present.

In correspondence with the small dimensions of the organ in this class, the nutrient vessels are not of considerable size. Sometimes they consist of a single branch, as in the cod, or several, as in the salmon. In the former, the splenic artery, which is a small branch, is derived from that division of the cœliac artery which supplies the stomach and intestinal tube, of which it is the smallest and most unimportant branch. The splenic vein, which is rather larger than

the artery, empties itself into the mesenteric vein, but does not form one of the main trunks of the vena portæ.

MINUTE STRUCTURE OF THE SPLEEN IN FISHES.

The structure of this organ in fishes presents the same general characters that are observed in the higher animals; at the same time some of these are so modified in the present class, that great difference of opinion has arisen as to their actual structure, the office assigned to them, and the analogy they may bear with like structures in the higher vertebrata. These circumstances will, I hope, be a sufficient reason for my entering somewhat minutely into a detailed account of them.

The *external tunic*, which in all fishes is thin, delicate, and transparent, invests the entire circumference of the organ, and is reflected into its interior at the point where the vessels enter. This membrane is elastic, presenting the appearance of a pale granular fibrillated membrane, the fibrillæ running chiefly in the direction of the long axis of the organ, a few traversing it both in the transverse and oblique direction; these fibres are composed partly of the white, and partly of the yellow elastic tissue, the latter existing, however, in small proportion to the former. I have not been able to detect the existence of any muscular fibres in this tunic.

The *trabeculæ* pervade the soft tissue of the spleen in every direction, but they are smaller and

more delicate than those found in the mammalia; they are derived partly from the external capsule, and partly from the internal prolongation of the capsule which forms the sheaths of the vessels. They are composed partly of white, partly of the yellow elastic tissue, the fibres of which lie parallel with one another in the long axis of the trabeculæ. Interspersed among these fibres are numerous oval or circular shaped nuclei; their texture is homogeneous, and they contain no nucleoli. I have in no case observed muscular fibres in these structures.

The *pulp* of the spleen, which fills up the interspaces formed by the trabeculæ, is of a dark reddish brown, and in some cases black colour, from the large number of blood globules and pigment granules, which it almost constantly contains (fig. 60). This structure is composed of a quantity of fine granular plasma, containing a large number of nuclei, which form the chief component of the pulp. The nuclei are of two kinds. The first, which are the largest, are somewhat variable in size; they are circular, pale in colour, and either homogeneous or of a fine granular structure. The *second* variety are *much smaller* than the above, of a homogeneous structure, but present a *dark refractive* outline. Around some of these may occasionally be observed arranged a mass of fine granules in a circular form, or the nucleus becomes included in a delicate cell-wall, the cavity of which sometimes contains numerous granules. So far the structure of the pulp presents in every respect the same appearances that have been observed in the

higher vertebrata. Besides these, however, it contains a large number of normal blood corpuscles, present-

Fig. 60.*

ing an oval or circular form, and containing in their interior a small circular or oval-shaped nucleus. It not only contains, however, normal blood discs, for many others may be observed, in which an evident process of disintegration is being effected. Now in fishes this appears to take place in various ways. In the *cod*, *perch*, *eel*, and *bream*, this process is similar to what I have already demonstrated in reptiles, birds, and partly in mammalia; many of the blood globules

* A portion of the pulp of the spleen from the tench: *a a.* Normal blood corpuscles; *b b.* Blood corpuscles altered in form and colour; *c c.* Blood corpuscles intersected by elongate acicular-shaped crystals; *d d.* Similar crystals free; *e e.* Dotted nuclei.

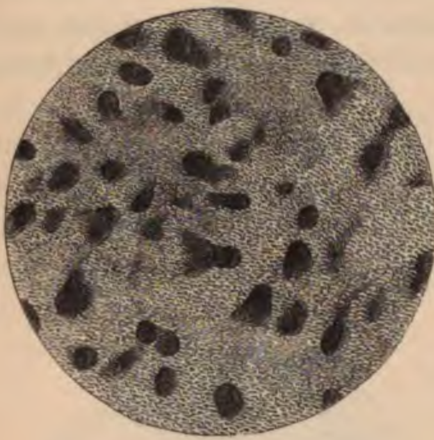
being observed to have lost their usual appearances; they were smaller in size, and their margins had shrunk and become contracted and indented; the outer margin of the blood disc presenting an unusual dark appearance, and the nucleus becoming of an irregular form, and of a faintly granular texture; in some, the wall of the disc had become so contracted as to render the nucleus invisible.

Some of the blood discs did not present this wrinkled appearance, but were *pale* in colour, and their nuclei indistinct, the hæmatin being apparently set free. The corrugation and wrinkling of the corpuscles proceed until they become small, reddish-brown or blackish granular masses of an irregular form, which occasionally break up into numerous fine dark granules. In no single instance did I ever detect cells containing blood corpuscles, and from the large number of examinations that I have made, I feel confident in asserting that they do not ever exist. On the other hand, however, I have occasionally found the above-mentioned dark granular masses enclosed in a distinct vesicular envelope.

In the *tench*, *bream*, *barb*, and *eel*, other very interesting peculiarities are noticed in the disintegrating blood globules, besides those above mentioned, which I have not observed in other fishes. These are the formation of crystals in the blood globules (see fig. 60). These consist of numerous rod-shaped crystals, which are disseminated in very considerable quantity throughout the entire structure of the pulp. They are of a light reddish, or faint yellow tinge,

and vary considerably both in their length and breadth. They are insoluble in water, but acetic acid entirely dissolves them. They appear to be

FIG. 61.*



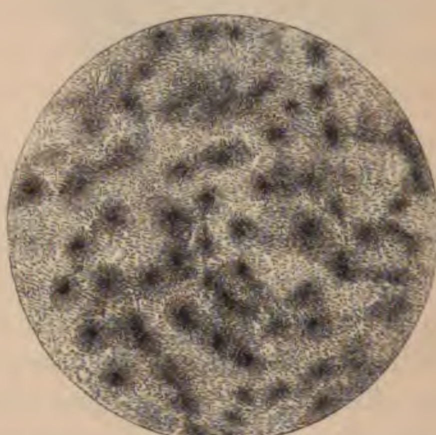
formed in the blood globules, which commonly present themselves with at first a single rod-shaped crystal intersecting either a part or the whole diameter of blood disc, or else two or many such crystals, all presenting a similar form, intersect a blood globule in various directions, and in some cases project from the margin of it. The outlines of the disc in these latter cases are less distinct, or have completely disappeared. Lastly, masses of such crystals, or free single crystals, unconnected with even the remains of blood globules, are observed disseminated throughout the

* A small portion of the spleen of the mackerel, magnified thirty diameters, to show the large amount of coloured pigment masses contained in the pulp.

entire structure of the pulp. The relation of these crystals with the blood discs, their evident formation in these structures, and their peculiar colour, clearly show that they must, in some way or other, be allied to the hæmatin of the blood, or possibly even consist of that substance which Virchow has called hæmaloidin, and which is a modified form of hæmatin.

I shall now proceed to consider the structure of those elements that are *peculiar* to the spleen of some fishes, and which apparently have some analogy with

FIG. 62.*



the Malpighian bodies of the higher vertebrata. In the *tench*, *perch*, *mackerel*, *herring*, *bream*, *and roach*,

* A small portion of the spleen of the herring slightly compressed. Magnified thirty diameters; showing the large amount of yellowish red corpuscles which it contains.

the entire mass of the spleen may be observed to be disseminated throughout with numerous small darkish-coloured points, (figs. 61 & 62) which mainly contribute to give to the organ its peculiar hue. Their colour varies. In the perch, they have a yellow or ochre tinge; in the tench, a dark yellowish red; in others they have a reddish black, or almost completely black colour. These masses consist of an external capsule, containing in its interior coloured elements. Their size varies not only in different animals, but in the same animal. Their average diameter is about the 250th or the 300th of an inch, their shape usually circular,

FIG. 63.*

more rarely oval, or irregular. Their number, also, as well as their size, varies considerably. In the

* A portion of the same as fig. 61, more highly magnified, showing the connexion of these corpuscles with the walls of the blood-vessels.

tench and roach they are large and very numerous, the whole of the arteries having their walls thickly studded with them. In the *perch* they are less numerous, and in the *bream* they are exceedingly *small* and *few* in number. These capsules lie thickly scattered on the walls of the small arteries (fig. 63), being either applied to their sides or at their points of bifurcation. They are also sparingly disseminated through the structure of the pulp, having no relation with the larger bloodvessels. These masses consist of a distinct external envelope, formed partly by the sheath of the vessel to which they are attached, and partly by a fine limitary membrane (fig. 64), by means of which these capsules are intimately adherent to the sheaths of the vessels, either by their broad bases, rarely by means of a thin and narrow peduncle, whilst occasionally they exist quite free (as is more frequently seen in the tench), their capsules consisting of a strong fibrous investment, the fibres composing which have a concentric arrangement, the usual coloured elements or colourless nuclei being contained in their interior.

The contents of these vesicles present a varied colour; they may be of a pale yellow, dotted with fine black granules, of a dark yellow, yellowish red, or of a dark greyish colour, and these variations are dependent upon the variations in the development and subsequent disintegration of the contained elements. These consist of an aggregation of orange yellow, or orange red, or blackish corpuscles, among which may here and there be observed a few dark

black, or dark red, or reddish brown granules. The structure, mode of development, and disintegration of these corpuscles I have most particularly examined,

Fig. 64.*

on account of the discrepancies in the description given of them by the German anatomists. Kölliker and Ecker describe their contents as *blood corpuscles*, presenting their normal appearance or undergoing a process of disintegration into the yellow, or red, or black granules, which are also contained in them, considering the capsules to be merely false aneurisms, ex-

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* The two drawings in this figure illustrate the connexion of the coloured corpuscles with the bloodvessels. From the spleen of the tench.

travasations of blood under the arterial sheath. It is only after the most repeated and careful examination in numerous fishes, that I hesitate to assent to this opinion, for in *no single instance* have I *ever* been able to detect either normal or changing blood discs in them. The results of my own investigations would lead me to consider them as a peculiar kind of colouring matter, which is formed as a secretion in distinct nucleated cells. If one of these capsules be torn up,

Fig. 65.*

and the contents examined, there may occasionally be observed a few vesicles, colourless, circular in form, and containing on their wall a distinct nucleus (fig. 65), the contents being either clear and pellucid,

* The drawings in this figure show the component elements of the coloured corpuscles in the tench, and illustrate the development of these structures, and the mode of formation of the colouring matter.

or else containing a few darkly refractive particles, not unlike oil globules. A few may occasionally be found presenting a pale yellow tinge, or two or three faintly yellowish coloured granules may be observed in them; some of these vesicles contain more numerous granules, which either partially or completely distend the cavity of the vesicle, the nucleus, as well as occasionally the cell-wall, becoming indistinct. The vesicles, with their contained coloured particles, being occasionally superimposed one upon another, more frequently these coloured particles are free, not being contained in cells, which have probably burst and set them at liberty. The form of the larger granules is most frequently circular, or irregularly circular, rarely of an elongate oval form; they vary in size; their average diameter is about the 2500th of an inch; they present a dark refractive outline, and are of a deep yellow tinge, or reddish, or reddish brown, or black; as frequently the contained corpuscles are more irregular and granular in form and structure.

These vesicles are not the only situation in which these corpuscles are found, for they may be observed free, lying on the walls of the vessels, sometimes in large quantities, and presenting a structure exactly similar to that above described.

In the *herring* and *eel*, and probably in many other fishes, similar masses may be observed lying on the walls of the bloodvessels, differing *only* in their structure from those above mentioned in the fact of their elements not being included in a distinct capsule.

In the *cod* no such *masses* are to be found at all,

but their elements may be observed disseminated through every part of the tissue of the pulp.

In the *flounder* and *whiting*, these coloured masses, which are small and not very numerous, are apparently formed by the disintegration of fat corpuscles. In both of these animals there occurs interspersed throughout the tissue of the spleen, a large quantity of perfectly free fat corpuscles, which exist either singly or become aggregated into small masses presenting a mulberry-like form; they vary in size, and in some cases have a yellowish granular tinge, which finally becomes more distinct; ultimately they become converted into yellow granular masses, smaller and less dark, but in every other respect precisely similar to the same masses mentioned above.

The peculiar form of the above-mentioned vesicles, their varying size, the structure of their investing capsule, and the connexion of these with the sides and the angles of bifurcation of the small arteries, all show some apparent relation with the Malpighian bodies of the mammalia, but they differ from them in the circumstance of their being found occasionally on the bloodvessels in the liver, and from the nature of their contents, which are not nuclei, as in them, but nucleated vesicles, containing a secretion in the form of coloured particles, or coloured particles alone; these probably have some intimate relation with hæmatin, or the colouring matters of the bile, for like them they are almost entirely dissolved by the action of liquor potassæ.

BLOODVESSELS AND BLOOD OF THE SPLEEN IN FISHES.

The *splenic artery* enters the spleen by many, or in the cod by a single branch; the vein and nerves, which are of large size, accompany it; the size of the artery is about one-half that of the vein, and its coats are much thicker; all these structures are enclosed by a thin sheath derived from the external tunic, and which also surrounds the larger branches given off from them. In the cod, the artery runs from the upper to the lower end of the organ, by the side of the vein, its size and the thickness of its coats gradually diminishing, giving off, either at right angles or obliquely from its canal, both large and small branches, all of which are of very inconsiderable size. These pass obliquely into the substance of the organ, divide and subdivide in the tissue of the pulp, the small arteries suddenly breaking up into a number of branches, each of which again subdivides, so as to form numerous long straight capillaries, which unite into a delicate capillary net.

The *splenic vein* is much larger than the artery, and its coats so much thinner, more particularly after its entrance into the substance of the organ, that the colour of the pulp is clearly visible through its walls. During its passage from the upper to the lower end of the spleen it diminishes in size, distributing numerous large and small vessels into the structure of the pulp, but which do not form a distinct capillary plexus in its substance.

The *venous blood* of the spleen in fishes contains a *much larger* number of *colourless corpuscles* than the arterial blood. In other respects I could not detect any difference between them.

The chief results that have been obtained from the present investigations on the comparative anatomy of the spleen are as follow:—

1st. The spleen exists without exception in all vertebrate animals.

2nd. It presents, however, by far its greatest development of structure, and consequently its function is most perfectly exercised in the mammalia, this being partly dependent upon the greater general completeness and requirements of their organization.

3rd. Part of the offices of this organ are plainly those of a diverticulum for blood. This is especially seen in the diving animals, where its large size is undoubtedly associated with the considerable obstruction to the circulation which takes place under these circumstances. Its large size, also, in those animals in which assimilation of food *rapidly* occurs, and in which consequently new material is suddenly added to the circulation, as compared with its extremely diminutive size under the opposite conditions, also affords evidence of its diverticular function.

4th. The total absence in reptiles and fishes of one of the main elements of this gland in mammalia and birds is in perfect accordance with their low grade of organization and the remarkable faculty they possess of sustaining hunger for almost an unlimited period, whilst in the former they form a ready, although a

scanty, sinking fund for albuminous materials, that can be rapidly given up to the blood during their temporary and occasional abstinence, and which cannot be borne by them with impunity for any long period.

5th. Its function, then, is not for specific, but for general purposes, serving to regulate, under many varied and opposite conditions, the quantity and also the quality of the blood.

PART V.

PHYSIOLOGY OF THE SPLEEN.

In the preceding investigations I have endeavoured to elucidate, step by step, the development of the spleen and the various elements of which it is composed. I have also demonstrated the minute structure which these elements present in their mature state, and their exact composition as far as chemical analysis can determine. The exact composition of the fluids that traverse its substance, whether blood or lymph, has also been displayed, and a rigid comparison instituted between them and like fluids from various other parts of the animal body; the laws also which regulate the very considerable differences observed between them have been strictly examined. These observations do but constitute the facts, the materials, from which I must now, in the next place, deduce the function and uses of the spleen. It is not my intention, in this part of my subject, to attempt to controvert the very numerous theories that have been, even during the last few years, adopted by physiologists as regards the function and uses of this organ. If the statements that I have already made, as regards the structure and composition of the

several elements of this organ, are correct, many of the theories that have been advanced—that, for instance, which ascribes to the gland the formation of a peculiar lymph, or that, again, which attributes to it the office of generating the blood corpuscles, or even that theory that has been so lately adopted of its *sole* function being that of destroying the blood corpuscles, each and all of these have to a certain extent been completely and decisively disproved. I will rather confine myself to the facts that have been ascertained from my own investigations, and collate from them the function and uses of the organ.

The result of these investigations would lead me to conclude that the function of the spleen *is to regulate the quantity and the quality of the blood.* I must now attempt to show if the above-mentioned facts bear out this conclusion.

In the first place, it will be necessary to prove that the spleen does regulate the *quantity* of the blood; under what circumstances it performs this office; how it is performed; and of what use is the application of this office to the well-being of the animal economy.

It will be obvious that the framework of any organ whose office it may be to regulate the quantity of the blood, would present a structure adapted in every respect to the extreme alterations of size that, under certain circumstances, such organ must undergo, extremes of size that can only be permitted by a highly elastic structure, such as the external capsule and the trabecular network of the spleen in every respect present. Now, this structure is not only

found in man and the mammalia, but also to a greater or less extent throughout the whole of the vertebrate classes, although its more perfect development in the former class is in exact accordance with its larger size and greater functional activity. The existence of such a structure alone appears to add very considerable weight to what I have already proved does really exist—namely, considerable and extreme variations in the size of the spleen.

It is also equally obvious that an organ whose office, it is supposed, is to regulate the quantity of the blood would be furnished with bloodvessels, and more particularly veins, of such size as to be capable of containing, under certain circumstances, a varying amount of blood; and in the spleen such an arrangement does exist, for the veins, not only the larger trunks, but also the smaller branches, are of such considerable size as to lead to the inference that their use is not limited to the carrying off the altered nutrient blood. Their size alone indicates their further use of retaining, under certain circumstances, a large amount of blood.

The very considerable size of the veins of the spleen has been observed to be almost constant throughout the whole of the vertebrate classes. A point, too, of great importance is the large size they present in those animals where the spleen is required to occasionally hold a considerable amount of blood, and their extreme diminution in other animals placed under exactly opposite conditions. If other facts were wanting, I think the existence of a highly elastic

and distensile framework, enclosing a large and highly complex venous mesh, sufficient proof in itself to show its application in regulating the amount of blood.

But the most satisfactory proof that we can possess is that that the spleen really does contain, under certain circumstances, a varying amount of blood, and that that amount is to such an extent as to justify us in concluding that the organ serves to regulate its quantity. It is hardly necessary again to refer to the table of experiments which contains the amounts of blood that have been obtained from the spleen under many varied conditions; suffice it to show that an amount varying from fifty grains to ten thousand has been obtained; the extreme variations of quantity, it is true; but the intermediate quantities themselves are so different, so varied, and so utterly out of proportion to the quantity that may be procured under the same circumstances from other organs, that the only conclusion at which we can arrive is, that the variation in the amount of blood is in exact harmony with the structure of the organ adapted to contain it.

We are now in a position to explain another fact which will also tend to prove the above proposition. Extreme differences in the size and weight of the spleen have been observed, differences not only observed at all periods of life, but at the same age under opposite conditions. The above-mentioned facts of the variation in the amount of blood contained in the bloodvessels will *partly* serve to explain these differences.

I think, then, the existence of a highly elastic structure in the capsule and trabeculæ of the spleen, the latter containing in its interstices a vast mesh of veins, presenting, under certain circumstances, the most extreme variation in the amount of blood, each and all of these facts tend to prove that the spleen does regulate the quantity of the blood.

Let me now consider *under what circumstances* it performs this office.

The variation in the amount of blood contained in the spleen is regulated by the amount of blood in the vascular system generally, an increased quantity in the spleen being dependent on an increased amount in the vascular system, whether produced by the gradual conversion of *solid* food into blood, or by the absorption of *fluids* introduced into the system, or by the actual transfusion of blood either into the portal or the general venous system (as seen by experiments); in each and all of these cases an increase, and a considerable one, in the quantity contained in the spleen, is observed. It is hardly necessary again to refer to a detailed account of the experiments which have led me to draw the above-mentioned conclusion. It is there seen that after each fresh ingestion of solid food, where sufficient time has been allowed to elapse for its conversion into blood, and where, consequently, there is an increase in the volume of the circulation, that the spleen contains a considerable quantity of blood, a much larger quantity than either *previous* to the completion of that process, or *some time after* perfect digestion has been effected. The large size

also of the spleen in those animals where, from the nature of their food, digestion is more *rapidly* performed, as compared with its diminished size where the process of assimilation extends over a much longer period, appears to be in harmony with these facts. In like manner, also, the introduction of *fluids* in the body, after their absorption has been completely effected by increasing the volume of the blood, is attended with a considerable increase in the amount of blood in the spleen, as compared with the quantity contained in the organ where fluids have not been introduced. The intimate connection of this organ with the portal system would at first lead one to infer that its office was to regulate the amount of blood contained in this system of vessels alone; but the experiments already detailed show that wherever the volume of the circulation is increased, whether by tranfusion of blood into the portal or into the general venous system, the spleen exerts its office in either case to regulate the quantity of the blood.

The spleen not only serves to *regulate the quantity*, but acts, under certain circumstances, as a *reservoir* for blood during obstruction of the circulation, a result of the suspension of respiration, which occurs frequently in some of the mammalia whose peculiar habits require such a provision. The beautiful adaptation of such a structure in harmony with the peculiar requirements of the animal adds greater weight to my opinion of the spleen serving as a reservoir to regulate the amount of blood, than the most delicate experiments that man is capable of performing. But

even to render these facts more perfect, obstruction of respiration, and consequent obstruction of the circulation by experiments, as I have also previously shown, have been attended with considerable accumulation of blood in the spleen, an accumulation, in fact, far greater than I have observed under any other circumstances.

The spleen also serves to regulate the amount of blood according to the nutrition of the animal, independent of the varying periods of the digestive process, the spleen in well-fed animals always containing a much larger quantity of blood than in ill-fed or starved animals. Under the former circumstances a larger proportional amount of blood is contained in the organ after the completion of digestion than in ordinary fed animals; under the latter circumstances, the ingestion of a large supply of food causes no appreciable difference in the amount of blood in the spleen. Now, the causes of these differences are to be easily explained; they are still varied by and depend upon the amount of blood in the vascular system generally. In well-fed animals, where the volume of the circulation is naturally considerable, and where every fresh ingestion of food increases its amount, the spleen is required to contain a large amount of blood, a larger amount than under ordinary circumstances. In ill fed or starved animals, on the contrary, where the volume of the circulation is reduced to the greatest possible extent, the spleen contains not more than a few drops of blood, and even the fresh ingestion of food under these circumstances

does *not* increase the amount in the system to such an extent as to require the spleen to contain the increased addition to the already diminished quantity. Now although these are the only conditions, as far as I have been able to ascertain, under which the spleen in a normal state serves as a reservoir for blood, or as a regulator of its quantity; still there are many circumstances under which an abnormal condition of other organs serves to produce in the spleen such considerable and extreme variations in size, chiefly depending upon its containing a large amount of blood, that these facts add still more weight to my opinion of the function of the organ. It is well known that in certain diseased conditions of the liver, where there is great obstruction to the portal circulation, the spleen becomes greatly enlarged, its venous trunks inordinately dilated, and containing a very large amount of blood; in these cases, in fact, there appears no other limit to its distension than the capacity of the abdomen. Again, also, in many cases of cardiac disease, where the current of the circulation is much retarded, the spleen is occasionally greatly distended, and holds a large amount of blood. The spleen in both cases serves as a reservoir for blood, as a safety valve to the circulation.

I think the above mentioned facts distinctly prove that the spleen *does* regulate the *quantity* of the blood, and that the circumstances under which that amount is regulated depend upon the condition of the blood-vessels, the spleen containing a larger quantity during a replete condition of the vascular system, whether

caused by a fresh ingestion of solid food, the absorption of fluids, or the introduction of blood itself; the spleen containing a smaller quantity under the opposite conditions.

It must now be seen how, and in what manner, the spleen performs this office.

I believe that the power which the spleen possesses of regulating its amount of blood, depends *entirely* upon mechanical properties. I think that it is natural to conceive that an organ like the spleen, composed of a highly elastic and distensile tissue, containing a dense and complicated venous plexus, connected by a large trunk with a part of the vascular system, would naturally become more distended with blood where the bloodvessels to which that organ was connected were replete with blood: the moderate obstruction to its emerging blood, which the repletion of the venous system affords for a certain time after the fresh ingestion of solids or fluids, would serve to give rise to a distension of the organ with blood; but as the vascular system resumes its former dimensions, from the newly introduced blood becoming expended in the various processes of nutrition and secretion, the vein evacuates its contents, compressed by the elastic capsule and sheaths, the entire organ collapses, and the spleen resumes its former size.

The preceding observations have, I hope, satisfactorily demonstrated that the spleen serves to regulate the *quantity* of the blood, under what conditions the organ performs this office, and in what manner it is performed; they serve to demonstrate, in fact, a part

of the *function* which the spleen performs. Let me now consider of what use is the application of this function to the well-being of the animal economy. What use in the living animal is fulfilled by this temporary retention of blood? In obedience to what laws or demands of the system, does the spleen render up again that which it had retained?

The answer to these questions can be easily conceived from the preceding remarks. If the spleen under certain conditions retains a considerable amount of blood, and simply dependent on a replete condition of the vascular system, whether caused by the sudden addition of solid or liquid food, its use appears to be mainly that of containing the additional amount which the over-distended vessels cannot, without considerable inconvenience, retain; and this theory of its use receives additional weight from the circumstance of its much *larger size* in those animals in which, from the nature of their food, digestion is more *rapid*, and the new material becomes *more rapidly* introduced into the circulation. Whilst its *extremely diminutive size* in those animals where the digestive process extends over a very considerable period, and where, consequently, the new material is more *slowly* added to the circulation, equally suggests that its use is not required, as an *over distended* condition of the vascular system does not take place. If the spleen, also, under certain conditions, contains a large amount of blood, dependent upon obstruction to the circulation, caused by impeded respiration, as we see to be normally the case in some of the diving animals, its evident use is

to serve as a *reservoir for blood*, as a safety-valve to the circulation; a safety-valve which can, from its structure, be suddenly called into use, and as suddenly become quiescent, when the conditions under which its activity is excited subside. Its *use*, then, is a reservoir for blood, a safety-valve, not to any particular system of vessels, or to any organ, but to the system generally, to the general circulation, — an organ called into use where a replete condition of the bloodvessels, or obstruction to the circulation in those vessels, would be attended with extreme inconvenience, if such organ did not exist; an organ that, from its structure, can be called into action suddenly and occasionally, for each and every requirement of the vascular system, as far as regulating its quantity is concerned, and which can as readily again restore to the circulation that which it had temporarily retained.

Let me now endeavour to show, in the second place, its still more important office, that of regulating the *quality* of the blood.

In the first place it will be necessary to ascertain, whether the spleen *does* regulate the *quality* of the blood; which of its numerous constituents the organ modifies; by what elements of the organ is this modification produced; under what conditions it performs this office; and lastly, of what use is the application of this function to the well-being of the animal economy.

It is obvious that if the spleen serves to regulate the *quality* of the blood generally, the constituents of

its emerging blood (as compared with that which enters the gland) should present certain differences, that those differences should be constant, but variable, in amount, and such as are not found in the blood of any other part or organ. Before proceeding one step farther, this fact must be distinctly and clearly proved:—Does the *splenic venous blood* present any differences *peculiar* to itself? Are those differences sufficiently constant to warrant our concluding them to be peculiar to this blood? Does blood taken from other parts of the body present the like peculiarities? It is needless here to enter again into a detailed account of the experiments already related, in which the composition of the *emerging venous blood* has been compared with that which enters the gland, and with other venous blood, both from the general and also from the portal venous system. Suffice it to say, that in each and all of these cases, and in each of the experiments made, a very considerable difference was detected between them; a difference, variable in its amount under certain circumstances, but which could only be attributed to the influence the spleen exerts on the blood traversing its substance.

So far these facts, I think, clearly prove that the spleen *does* serve to regulate the *quality of the blood.*

Let me now consider which of the numerous constituents of this complex fluid does the organ modify?

The most important constituents of the blood, modified by the action of the spleen, are the *blood globules*, the iron among the inorganic constituents, *the albumen*, *the fibrine*, and lastly, *the serum.*

Of all the elements of the blood, none present such striking and well-marked differences as the blood globules of the splenic venous blood, and these differences not only relate to their quantity, but also to peculiarities in their structure. As regards the amount of the blood globules, it has been seen, from the experiments already mentioned, that their number presents a *very considerable diminution*, as compared with what enters the gland, or with other blood taken either from the portal or general venous system, and that this diminution presents very considerable variation; in some cases their quantity being less by one half, as compared with what enters the gland. The constancy of this peculiarity alone shows what a highly important influence the spleen must have on this constituent of the blood. But this diminution in the amount of the blood globules is not the only peculiarity which they present; for even some of those which form a constituent of this fluid, present certain peculiarities in their structure rarely to be met with in the blood from any other part or organ. I allude to their extreme variation in size, the peculiar wrinkled and corrugated appearance that many present, their occasional loss of colour, and the fact of their being occasionally found either in a normal or, more frequently, changed condition, included in cellular envelopes. The almost invariable constancy of both these phenomena, clearly proves that the spleen not only modifies the quantity, but also, to a certain extent, even the structure of the blood discs themselves. Such, in fact, is but a simple illustration of

the facts produced as the results of my analyses. Let me now consider by what elements of the spleen are these differences produced; in what tissue of the organ do these changes occur. In the examination of the pulp tissue of the spleen, it was seen that the *coloured elements* consisted for the most part of a large number of *normal* blood globules, varying, however, in number considerably under certain circumstances. It was also observed that in many animals the blood discs in the pulp presented an altered appearance, their colour becoming of a deeper tint, their size diminishing, and instead of their flattened and biconcave form, their margins and surfaces became wrinkled and corrugated, in some to a slight, in others to a considerable extent: finally, they were seen either singly, or grouped together in masses, to become changed into deep red, or reddish yellow, brown, or occasionally black pigment masses; or they gradually broke up into a variable number of small and similar coloured pigment granules. More rarely, indeed, delicate acicular-shaped crystals of small size, and of a yellowish red tinge, were observed to be formed in the blood globules themselves, existing in the pulp either as free crystals, or as numerous crystalline groups, in large quantities.

Again, in other animals, the normal blood discs, or those in which their colour and form were somewhat changed, were observed to be enclosed in a distinct cellular envelope, containing a variable number of them, and presenting precisely the same changes proceeding in them as is described above as occurring

in the free blood globules. Finally, the substance of the pulp itself contained a variable, but occasionally a very considerable quantity either of free coloured pigment granules, or similar granules enclosed in cells, evidently the débris of the altered blood discs. The examination of the bloodvessels of this organ clearly served to show also by what means the blood globules became extruded into the substance of the pulp. It was seen that although many of the arterial capillaries could be distinctly traced as continuous directly with the veins, still there were a large number which apparently were lost in the substance of the pulp traversing channels in this structure, the walls of which were simply epithelial previous to their junction with the veins; the veins also were demonstrated as not forming a network with continuous walls, but communicating with each other by intercellular spaces in the substance of the pulp.

It is easily conceived, from these observations, how, under certain circumstances, extrusion of some of the blood globules would occur in the substance of the pulp during the temporary, and occasionally considerably distended, condition of its vessels.

Now the existence of blood globules in the pulp tissue, and the various changes which they undergo, as well as the disposition of the vessels, as admirably adapted to permit of such changes, have been observed to a greater or less extent in all the vertebrate classes. They have been occasionally observed in man; and among some of the mammalia, as the horse and ass, they are found to occur in extraordinary number,

and with considerable frequency; they have also been seen in the rabbit and the rat. In many birds, also, the same changes have in one or the other form been frequently noticed; whilst in some of the reptilia their constancy and occurrence in large numbers is somewhat remarkable. Lastly, the same changes have also been seen in fishes, and in some of these to a very considerable extent. These facts clearly show that the existence of normal and changing blood corpuscles in the pulp of the spleen, is not either an occasional occurrence, or a peculiarity simply confined to a single class of animals. Chemical analysis has also added strong confirmation of the coloured corpuscles of the pulp being formed from the blood globules, their analysis and the application of reagents to them, demonstrating their close similarity with the hæmatin of the blood.

The occasional, and in some animals the constant occurrence of normal and changing blood globules in the substance of the pulp, and their partial conversion into coloured pigment granules, or crystalline forms, the chemical analysis of which has shown to be identical with the hæmatin of the blood; the arrangement of the bloodvessels, as admirably adapted to admit of the occurrence of these changes under certain circumstances; the frequency of their occurrence throughout nearly the whole of the vertebrata;—all these facts, I think, are in exact harmony with the results of the analyses of the splenic blood, as far as the diminution of the blood globules is concerned. They clearly show that in all animals, under certain

circumstances, the spleen modifies the constituents of the blood discs during their transit through the organ, retaining them for a time in the pulp tissue, and changing the elements of which they are composed. I think, then, I may conclude that the spleen does *modify* the *quality* of the blood as far as *this constituent* of it is concerned. Let me now inquire under what conditions is this produced? What laws regulate its occurrence?

As far as the analyses of the blood show, the diminution in the amount of the blood discs is a constant occurrence, but that the extent of diminution is chiefly varied according to the general state of nutrition of the animal, and also according to the period of the digestive act.

The most marked variations were observed to depend on the condition of the animal as regards its general nutrition, the number of the blood discs being considerably diminished in the emerging splenic blood of *well-fed* horses, whilst in an ill-fed and starved horse the amount of the blood discs was *precisely similar* in the splenic and in the arterial blood. In the former case the extreme turgescence and distension of the vessels, which is, as we have already seen, a constant occurrence in the spleen of highly-fed animals, was favourable to the extrusion of some of the elements of the blood from the vessels into the tissue of the pulp. Whilst, on the contrary, in the latter case, the small quantity of blood in the organ and the lax condition of the vessels were unfavourable to such an occurrence; hence the absence of the diminution of the blood discs under these circumstances.

The period also of the digestive act modifies to a very considerable extent the amount of diminution of the blood globules in the emerging blood, the greatest amount being observed either where digestion is not going on at all, or during the early stages of that process; the smallest amount where digestion being finally completed, the new material becoming converted into blood, has increased the volume of the circulation, and extrusion of blood in the pulp is the result of the distended condition of the vessels of the spleen which occurs under these circumstances.

The spleen also appears to regulate the *quality* of its emerging blood as far as the amount of *iron* contained in it is concerned.

The blood of the spleen contained in the greater majority of cases a much larger amount of iron than was found either in the blood *entering* the gland, or in other venous blood, notwithstanding the number of blood discs was *diminished*. The changes observed in the pulp of the spleen will serve to explain these peculiarities. It is no doubt highly probable that under certain circumstances, when the blood discs undergo those changes that have already been described in the spleen, part, and probably in some cases the whole, of the iron which previously formed one of their essential constituents, becomes added to and forms part of the *unaltered* blood discs, and hence the increased amount in the emerging blood. Whilst, also, the large amount of iron occasionally found in the substance of the pulp, forming one of the chief elements of its inorganic constituents, evidently shows,

on the other hand, that it occasionally is stored up in the substance of the gland; hence the variation in the amount of iron contained in the emerging blood.

The most important constituent of the blood, next to the blood discs, which the spleen also modifies during its passage through the organ, is the *albumen*. Let me, in the first place, consider if it really does modify the amount of the albumen, we will then ascertain by what tissues of the spleen such modification is produced, and what laws regulate its extreme variation under certain circumstances. It will be unnecessary here to again enter into a detailed account of the analyses already recorded, as regards the amount of *albumen* contained in the emerging blood, as compared with what enters the gland, or with its amount in other venous blood. Suffice it to say, that the average amount was *greater* than was found either in arterial or other venous blood. It was also seen, that although the *average amount* was not much greater than in ordinary venous blood, considerable and very extreme fluctuation in its quantity was observed under certain circumstances; whilst, on the other hand, a uniformity was observed as regards the amount of albumen in the other kinds of blood in nearly *all* cases.

The results, then, of these experiments clearly show that during the transit of the blood through the tissue of the gland its *quality* is modified, as far as regards the amount of *albumen* contained in it.

Let me now consider by what tissues of the spleen such modification is produced.

We have already seen that the *colourless elements* of the pulp consist of granular matter, nuclei, and cells, in every stage of development, growth, and decay; that they form a very considerable portion of the pulp, lying in the meshes between the small capillary vessels, so as to be readily acted upon by the fluid ingredients of the blood which permeate their walls. There then can hardly be any doubt that this fluid is mainly essential in determining a continuous process of cell growth, which is, however, varied considerably under certain circumstances. It has also been seen that the results of the application of chemical re-agents to these elements have shown them to consist entirely of a *proteine* or *albuminous compound*, whilst the chemical analysis of the pulp itself proved it to contain a considerable amount of this ingredient. Extreme variation in the amount of these elements is observed under certain circumstances, and the periods of this variation are coincident with the variation in the amount of albumen contained in the emerging blood. The results of the experiments made to determine the laws which regulate these quantitative differences, have shown that the parenchyma cells of the pulp exist in much greater quantity, and form a very considerable part of the entire bulk of the spleen, in all animals where the amount of new material introduced *exceeds* that required by the waste of the body. In fact, under these circumstances, the blood overcharged with nutrient material is favourable to its albuminous compounds being stored up in the spleen, which serves consequently as a scanty, though

easily available sinking fund for nourishment, when the nutrition of the body is perfectly performed.

On the contrary, the parenchyma cells do not only diminish in number, but they do not *actually exist at all* in those animals in which new material has not been supplied in sufficient quantity for the waste of the body; in fact, where starvation had been produced. There can be hardly any doubt, under these circumstances, that the albuminous materials set aside in the spleen under the form of a lowly organized tissue, again become dissolved, and enter the circulation by the veins, in order to supply the temporary and occasional demands of the system.

The parenchyma cells of the pulp are not, however, the only tissues of the spleen concerned in regulating the amount of albumen in the blood. The Malpighian bodies, also, I believe, very materially assist in performing this office. It has been seen that these bodies, which exist in large numbers, and present every variation in size, are closed glandular vesicles, placed at the angles of bifurcation of the smaller arteries, and consisting of an external membrane, forming a closed cavity, containing a secretion in its interior *essentially albuminous* in its composition; these vesicles presenting on their outward surface a dense but delicate capillary mesh, adapted to secrete the matters contained in their interior, their surface being also covered by a dense mesh of veins, admirably arranged to carry off the secreted material, which they discharge under certain circumstances. Now, the extreme variation in size which these bodies undergo

under certain conditions, is exactly coincident with the increase or diminution in the number of parenchyma cells in the pulp, with the increase or diminution in the amount of albumen in the blood.

In the experiments already detailed it has been seen that these bodies vary considerably in size, according to the nutrition of the animal, and according, also, to the period of the digestive act, their size being considerable when the nutrition of the body is being perfectly performed, and also when a considerable amount of new material is added to the blood. Under these circumstances, it is not improbable that these glands serve to separate from the blood a certain amount of the albuminous nutritive material, that it contains in such increased quantity under these conditions. On the other hand, their extreme diminution, nay, even their total absence, in starved animals, or where the introduction of new material is only for a time suspended, evidently shows that their contents are discharged; the albuminous material previously stored up in these glands as a sinking fund of nutriment, during a highly nutritious condition of the blood, discharging their contents into the circulation when the requirements of the system need such a supply.

I believe that the colourless elements of the pulp, as well as the Malpighian bodies, both of them serving as storehouses of nutriment, are used as a sinking-fund for albuminous materials during those conditions where the supplies exceed the demands of the system. On the other hand, where the wants of the

system are not supplied in sufficient quantity by the introduction of new material, the albuminous materials stored up in the spleen restore again to the blood that which they had for a period retained.

Let me now consider under what conditions is the amount of albumen in the blood varied; and if these variations correspond in every particular with similar variations in the amount of the parenchyma cells, and the size of the Malpighian bodies. The principal facts ascertained show that in well-fed horses the amount of albumen is very *inconsiderable* during the final completion of the digestive process. This precisely corresponds to the extreme development of the parenchyma cells of the pulp, with the extreme enlargement of the Malpighian glands under the same conditions. On the contrary, *before* digestion, and during its early stages, the amount of albumen is increased in quantity; this also corresponds with the small size of the Malpighian glands, and the diminution in number of the parenchyma cells during the same periods.

Lastly, in starved horses the constitution of the emerging blood is almost precisely similar to that which entered the gland: this is in exact accordance with the absence of the Malpighian bodies and of the chief part of the parenchyma cells during the same period; the blood, in fact, under these circumstances is not modified in any way during its transit through the organ.

We may fairly conclude, from these facts, that the spleen regulates the *quality* of the blood as far as the

amount of *albumen* contained in it is concerned, and that this variation is produced by an interchange which takes place between the blood circulating through the spleen, and the elements of the pulp, and the Malpighian bodies; these serving to draw from the blood, under certain circumstances, its surplus amount of albuminous matters, mainly derived from the successive additions of new nutritive material, which is not allowed to accumulate in the blood till its use is required, but is set aside within ready reach, whenever the demands of the system require a quickly available though scanty supply.

The spleen also serves to regulate the *quality* of the blood as far as the amount of *fibrine* contained in it is concerned.

The results of the analyses already detailed have shown that the average amount of *fibrine* contained in the blood after its transit through the spleen, is much greater than in the blood entering the organ or in other venous blood; and the fact of its constancy, under all circumstances, although varying in amount, clearly shows that the spleen must exert some modifying agency on this constituent of the blood. As far as I have at present been able to ascertain, this variation, which is occasionally very considerable, is not owing to the influence which the elements of the tissues of the spleen have upon the blood, but apparently stand in some relation with the diminution of the blood discs in this fluid, and their consequent disintegration in the pulp tissue of the spleen, inasmuch as an exceedingly *small* amount of fibrine is contained in the blood

where there is little diminution in the amount of the blood corpuscles; on the contrary, a much larger amount of fibrine is usually found where the blood discs are much diminished in number. It would thus appear as if *part, at least*, of those *colourless elements of the blood discs* which undergo disintegration in the pulp assist in forming the increased amount of this element of the blood, whilst the colouring matter forms the large amount of *coloured* corpuscles so frequently found in the substance of the pulp, and which, as we have seen, presents the closest analogy with the hæmatin of the blood. It is not improbable, also, that *part* of the colourless elements of the blood discs may assist in forming the *increased* amount of albumen contained in the emerging blood.

The last peculiarity that it is necessary to consider is the *deep reddish colour* of the serum of the blood after its passage through the tissue of the spleen.

In the already detailed microscopic examination of this blood, it has been seen that after its exit from the spleen, it contains occasionally a considerable number of coloured corpuscles and coloured crystals, that appear to be in every respect identical with the hæmatin of the blood; *similar* corpuscles and occasionally *similar* crystals have been detected in the pulp of the spleen, and they appear to be formed directly from the blood discs, and to be identical with their colouring matter. The only inference that can be drawn from these facts, taken in connexion with the *constancy* in the colour of the serum, is, that the colouring matter found in this fluid, and which exists

in it chiefly in solution, is identical with the colouring material found in the tissue of the pulp, being removed from this tissue by means of the bloodvessels, and so again entering the circulation. What becomes of this colouring matter? Kolliker states that it goes to form the colouring matter of the bile; but this is certainly not the case, as, in the first place, neither the colouring matter itself in the spleen or in its emerging blood presents the least appearance to biliary pigment, as the application of chemical reagents upon it shows. Again, also, the removal of the spleen in animals does not affect the colouring matters of this fluid; it exists in equally large quantities. And, lastly, the colouring matter of the bile existing previous to the development of the splenic vein in the evolution of the chick, and consequently before the spleen can have transmitted to the liver any blood changed by the action of this gland, all these facts show that the colouring matters of the spleen, carried away in solution in the emerging blood, do *not form* the colouring matters of the bile. It is not improbable that *part* may enter the circulation, and go to form the colouring material for new blood globules; *part* also may become changed in the hepatic cells into bile pigment; but that the *whole* of the bile pigment is formed from this colouring matter, the above facts clearly disprove.

I think that the above detailed facts clearly prove that the spleen does regulate the *quality* of the blood, the *tissues* of which this organ is composed serving, under certain conditions, to modify very materially

the blood transmitted through it. The above facts also show that the constituents of this fluid so modified are the *blood globules, and the iron, the albumen, the fibrine, and the serum.*

It has been seen that, under certain circumstances, chiefly depending upon a replete condition of the vascular system, the distended vessels of the spleen allow in some cases the extrusion of a varying number of blood discs. These immediately undergo a series of changes in the pulp, by which their colouring matter is modified to form the coloured pigment corpuscles which the pulp contains, part also being carried off by the emerging blood, giving to the serum its deep reddish tinge, the colourless elements of these discs forming the increased amount of fibrine, and probably also a part of the increased amount of albumen contained in the emerging blood. At the same time, the iron which they contain is either stored up in the tissue of the spleen with the other elements of this gland, in which it occasionally exists in large quantity, or it is carried away in the blood, which is also found occasionally to contain a large amount. That this is a correct explanation of the changes which occur in the spleen is also, I think, borne out by the results of chemical analysis. They have shown, in all cases, that a varying though considerable diminution in the *blood discs* is a constant peculiarity of the splenic venous blood; that the amount of *fibrine* contained in it appears to bear some proportion to the extent of diminution of the blood discs; that the proportion of iron is variable; and that

the deep reddish-brown colour of the serum is also a constant and well-marked peculiarity. It has also been seen, from the previous facts, that when the vascular system becomes charged with a large amount of nutritive compounds, by the successive addition of new material, that the blood circulating through the spleen is deprived of a large amount of albumen, which the parenchyma cells of the organ and the Malpighian corpuscles assimilate to themselves in great abundance and with extreme rapidity. On the contrary, when the supplies of the system are not equal to the demands, these elements of the spleen again restore to the blood those nutritive products which they had previously retained; hence the very extreme variation in the size of the Malpighian bodies and the amount of the parenchyma cells; hence the considerable fluctuations in the amount of albumen contained in the emerging blood.

These facts merely serve to represent the *function* of the spleen; they merely serve to show what the organ does. We must now, lastly, consider of what *use* is the application of this function to the animal economy? What use does the spleens erve by disintegrating, under the conditions already mentioned, a large number of blood globules? What use does the spleen serve by its temporary abstraction from the blood of its albuminous compounds, and its equally rapid restoration of those materials to this fluid under certain circumstances? Lastly, is such use absolutely necessary for the maintenance of life?

We have already seen what use the function of the

spleen affords to the animal as regards its regulating the *quantity* of the blood, serving as a reservoir, a safety-valve to the general vascular system, called into use where a replete condition of the bloodvessels or obstruction to the circulation in those vessels would give rise to extreme inconvenience. The purpose, then, the elastic framework of the spleen, and the extreme size of its numerous veins, serve for the *quantity* of the blood, the parenchyma cells of the organ and the Malpighian corpuscles serve for its *quality*, for under precisely the same conditions which determine a large *amount* of blood in the spleen is its *quality* also modified. It appears absolutely necessary that, where the successive addition of new material increases not only the *quantity* but also the nutritive condition of the blood, its *quality* should be as essentially balanced as its actual amount. The successive addition of new material is no more allowed to *accumulate* in the blood than is its actual quantity; the increased addition of new material, when not immediately required by the system, producing as much inconvenience as the actual increase in the *amount* of it alone. Under such circumstances it is admirably adapted that the spleen should balance not only the quantity but also the quality of the blood, regulating the amount and modifying the component elements of the blood discs, modifying the amount of albumen in the blood; that it should be an organ appended to the vascular system to regulate its ever-varying conditions, and in close contact with the same system of vessels, which are mainly incidental

to the introduction of the new material into the circulation. When these vessels are carrying into the blood, by the digestive process, new material, the fulness of the vascular system is attended with a distension of the spleen with blood, and accumulation of nutritive compounds in its tissues. On the other hand, where the introduction of new matter is not being effected, the organ as rapidly rids itself of its accumulated blood; at the same time the nutritive matters previously stored up in the gland are given up to the blood, taking the same course in the circulation, and consisting, in fact, of the same elements which the blood itself derives from the digestion of the food.

Is such use absolutely necessary for the maintenance of life? The complete removal of the spleen in many of the mammalia is an experiment that has been performed, in very numerous instances, by many anatomists, from the very earliest period up to the present time; and the results that have been obtained have shown most conclusively that, in each case, its abstraction did not in the least interfere with a due performance of the functions of the body or with the maintenance of life; on the contrary, in many cases it is stated that they even improved in condition. The results of my own experiments would lead me to concur in the above statements. I have removed the spleen from a dog, from cats, and rabbits. In all cases the animals survived the operation, and did not appear to be in the least affected by the absence of the organ. On the contrary, I

noticed that in two of the cats kept for a considerable time, they certainly *improved much* in condition, and grew to a much larger size than other cats of the same age where the organ was intact. These facts clearly show that the spleen is an organ, the use of which is not absolutely necessary for the maintenance of life. Such experiments were, however, hardly requisite in order to arrive at this conclusion, for the results of the comparative anatomy of the gland have shown that its extreme diminution in the lower vertebrata is in harmony with the decrease in its functional activity and the more limited use which the organ performs, whilst its minute size in the ophidia shows that its use can be of little, if indeed of any, importance in this class. Now, these facts do not, I think, in the least invalidate the conclusions at which I have arrived concerning the use of the spleen; for although they show that its existence is not indeed necessary for the maintenance of life, still its large size in the higher vertebrata is dependent upon the greater general completeness and requirements of their organization, serving as a most perfectly adapted appendage to their vascular system, to regulate and balance under the most varied conditions the differences in the *quantity* and in the *quality* of the blood.

But if the spleen does possess the office that I have assigned to it, how is it that its removal in the mammalia is not attended with any inconvenïence, nay, how is it that its removal after some time is, on the contrary, attended with a more improved condition in the nutrition of the animal? In what manner is the

quantity and the quality of the blood then regulated? As far as regulating the amount of blood is concerned, there can be hardly any doubt that, under the above conditions, the periodical increase in the quantity of the blood, which, were the spleen intact, would be retained a longer or shorter period in its highly dilatable venous mesh, is now distributed over the whole system, so that the bloodvessels generally contain more blood than under ordinary circumstances; hence probably the symptoms of plethora noticed by Dobson in his experiments after the entire removal of the spleen from dogs, where new material was added in great quantity to the system.

But in what manner is its quality regulated? In what tissue or organ do the blood globules become modified. In what structures is the increased amount of albumen stored up for the temporary and occasional requirements of the animal? The results of my analyses, as well as those of Lecanu, Letellier, and Beclard, have shown that a slight diminution in the amount of blood corpuscles exists in venous blood generally, and if such is really the case, it appears highly probable that other parts and other organs do, to a limited extent, modify the elements of the blood discs during the transit of the blood through them. Consequently, it is easily explained how the removal of the spleen is unattended with any inconvenience as long as its function (as far as regulating the amount of blood discs is concerned) is performed by other parts or organs. Lastly, I think the results of the experiments that I have detailed warrant me in con-

cluding that, where the complete removal of the spleen has been effected, the increased amount of albumen derived from the successive addition of new material is stored up, not in any particular part or organ, but in the tissues generally; hence the highly improved condition presented by those animals in which the spleen has been removed for a long period. And although these elements cannot as readily, under the above conditions, be restored to the blood, as if the spleen had retained them, to be used at every occasion or requirement of the animal, still their removal from this fluid, where they exist in great excess, serves to effectually prevent the inconvenience which a too great accumulation of them in the blood would certainly occasion.

In concluding this treatise on the structure and use of the spleen, I am anxious to state that it has appeared to me unwise to enter into any detailed controversy with those whose opinions may be at variance with my own. It has appeared to me of more importance to confine myself entirely to the facts that I have obtained, as a result of my own investigations, and to deduce from them alone the structure and uses of this organ. It remains only for the reader to determine whether these conclusions are correctly drawn, and whether they serve to throw more light on the uses of this gland than those of my predecessors.

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